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Editor

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SOCIETY AND RELATED ACTIVITIES

Member-for-Member Drive

Although the Member-for-Member Drive started during the very last part of October, a few of the members of the Society responded promptly and through their efforts a number of new members were secured. A list of these new members is given below.

It is expected that the next issue of the Journal will contain a much longer list as it will include the members secured during the month of November, together with the name of the proposer. The Membership Committee urgently requests that every member of the Society do his part in securing a new member.

New Members—October 1933

	Proposed by
Class "B"	
Wm. E. Hughes—General Manager, Sullivan Machinery Co., Claremont, N. H.	A. Vogel
J. R. Lambert—Chief Engr., The Phoenix Bridge Co., Phoenixville, Pa.	F. P. McKibben
Wm. G. Schneider—Research Asst., Copper & Brass Research Assn., 25 Broadway, New York City	W. H. Bassett
Walter B. Vanwart—Mgr., Wyatt Metal & Boiler Works, P. O. Box 1736, Houston, Texas	M. P. Hare
Class "C"	
Chas. J. Anchor—Shop Engr., American Car & Foundry Co., Milton, Pa.	John W. Sheffer
D. K. Crampton—Dir. of Research, Chase Brass & Copper Co., Waterbury, Conn.	W. H. Bassett
W. F. Crawford—Welding Supervisor, The Edward Valve & Mfg. Co., Inc., 1200 W. 145th St., East Chicago, Ind.	
Anthon G. deGolyer—Pres., Boron Alloy Tool Corporation, 500 Fifth Ave., New York City.....	J. J. Crowe
Irving J. Eales—Mgr. Welding Dept., Steel Sales Corp., 129 S. Jefferson St., Chicago, Ill.	W. Spraragen
S. Elvin Lloyd—Supervising Welder, Scott Paper Co., Chester, Pa.	
A. Leslie Pfeil—Welding Equipment Sales Mgr., Universal Power Corp., 1719 Clarkstone Road, Cleveland, Ohio	A. F. Davis
Carlyle H. Scott—Pres., Smith-Hamburg-Scott, Inc., 42–38 13th St., L. I. City, N. Y.	F. J. Giroux
Class "D"	
John D. Bert—Welding Supervisor of Field Erection, Stacey Bros. Gas Const. Co., Cincinnati, Ohio	F. P. McKibben
C. E. Wallace—The Oil Country Specialties Mfg. Co., Coffeyville, Kansas	W. Spraragen
Class "F"	
Paul D. Grubb—Coleman Electrical School, Kansas City, Mo.	
Albert Heeren—Coleman Electrical School, Kansas City, Mo.	

Welding Session

At the Annual Meeting of the American Society of Mechanical Engineers which will be held in the Engineering Societies Building during the week of December 4th a paper will be presented on Wednesday afternoon, December 6th, on "Welded Joints," by Mr. Everett Chapman, Chairman of the Joint Welding Practice Committee of the A. S. M. E. and A. W. S. All members of the Society are cordially invited to be present to discuss this paper.

Obituary

The Society has recently learned of the untimely death of Mr. William H. Namack, a member, on September 24th. Mr. Namack, aged fifty-six, died in a hospital at Springfield, Mass. His death is attributed to a combination of shock at the death of his daughter, Mrs. Francis O. Affeld, who was killed in an automobile crash at Huntington, L. I., two months before, and the recurrence of malaria, with which he was stricken while visiting the Philippine Islands some five years ago.

Mr. Namack was a member of the former local firm of Davison and Namack, makers of large castings. His name is famous at Cornell University in Ithaca for his skill in football. He graduated with the class of 1899. While Mr. Namack's residence was in Ballston Spa, he was financially interested in the New England Nut and Manufacturing Company at Westfield, Mass.

Mr. Namack was an active member of the AMERICAN WELDING SOCIETY and at one time was chairman of a sub-committee on research in the welding of cast iron. He was an active participant in the affairs of the Northern New York Section of the AMERICAN WELDING SOCIETY and served for a time as its chairman.

SECTION ACTIVITIES

BOSTON

The regular meeting of this Section was held on Friday, November 3rd, at the Watertown Arsenal, Watertown, Mass. This was a joint meeting with the Boston Chapter, American Society for Steel Treating. The following is the program:

2:00–6:00 P.M.—Afternoon Visitation

Induction furnace melting
Centrifugal casting of steel for cannon
The cold working of guns
Heat treatment of centrifugal castings
Demonstration of welding practice
Stress-relieving
Physical testing—Macro-Etch testing
X-ray demonstration

6:30 P.M.—Dinner and Entertainment

7:15–9:00 P.M.—Evening Program

"The Development and Functions of the Arsenal," Lt.-Col. G. F. Jenks, Commanding Officer.
"Welding of Structural Nickel Steel," Mr. W. L. Warner.
"Centrifugal Castings," Lt. S. L. Connor.
"Heat Treatment of Centrifugal Castings," Lt.-Col. G. F. Jenks.

CLEVELAND

The first meeting of the 1933–1934 season was held on Wednesday, November 8th, at the Cleveland Engineering Society, Hanna Building. Mr. Everett Chapman, Vice-Pres., Lukenweld, Inc., spoke on "Welding of Heavy Machinery." Mr. Chapman's talk on design and actual construction was illustrated with lantern slides and covered the problems of stress distribution, strain relief and the technique of actual welding of large mechanisms.

PHILADELPHIA

An invitation to attend the meeting of the Philadelphia Section of the Association of Iron and Steel Electrical Engineers, held on November 4th, was extended to the members of the AMERICAN WELDING SOCIETY. At this meeting, Mr. Everett

Chapman, Vice-President in Charge of Research and Engineering, Lukenweld, Inc., presented a paper on "Welded Design."

The next meeting of the Philadelphia Section will be held on November 20th in the Auditorium of the Engineers' Club. Mr. W. D. Halsey, Assistant Chief Engineer, Boiler Division, Hartford Steam Boiler Inspection & Insurance Co., will present a paper on "Unfired Pressure Vessels."

PITTSBURGH

A most interesting and instructive Inspection Meeting was held by the Pittsburgh Section October 26th, when members and about 150 invited guests were afforded an opportunity to witness under actual working conditions, the fabrication by welding, of the eight intake gates for the Boulder Dam at the plant of the Westinghouse Electric and Manufacturing Co., at East Pittsburgh.

The affair was arranged and handled most efficiently by W. W. Reddie of the Westinghouse Company, a member and former officer of the Pittsburgh Section.

The party assembled in the spacious company restaurant at 6:30 P.M. where they were treated to a most enjoyable meal furnished by Westinghouse, after which they were conducted to the plant studio where motion pictures of a recently developed traction type welder were shown in action on a railroad job.

Following the above demonstration, Mr. C. H. Jennings, Research Engineer for the Company, gave a general outline of the Boulder Dam Project and a detailed description, illustrated with slides, of the work under contract by the Westinghouse Company.

Leaving the studio the party was broken up into groups of 10 to 15 members, each with a guide in charge, to conduct them through the plant, where they were permitted to see just how this great project is handled. Considerable interest was evidenced by the close attention paid to the various operations, the size of the assembled units and the great amount of Class 2 welds, and the extraordinary accuracy in the finished sections never failed to bring forth expressions of praise from those familiar with the work involved.

The Officers of the Pittsburgh Section feel particularly grateful to Mr. Reddie for making it possible for the members and their guests to witness this work in course of construction and also to the Westinghouse Company for permitting the inspection.

EMPLOYMENT SERVICE BULLETIN

POSITIONS VACANT

V-53. Welding Engineer wanted. Must be engineering graduate from reputable college. Prefer man with Doctor's Degree and familiarity and training in machine design. Must have five years of experience in arc and resistance welding. Prefer man with experience in technical experimental development work, as well as practical shop production methods.

V-54. Inspectors on shipbuilding and naval materials. Applications for the positions of senior inspector, inspector and junior inspector must be on file with the U. S. Civil Service Commission at Washington, D. C., not later than December 1, 1933.

Optional branches are (1) ship construction (hull), (2) ship construction (mechanical), (3) ship construction (electrical), (4) engineering materials (electrical), (5) engineering materials (mechanical) and (6) hull materials. As a result of these examinations appointments will be made for inspection duty at shipbuilding plants where naval construction is in progress under contract at private shipyards, or at manufacturing plants where engineering materials are in process of manufacture under naval contract.

The salary range is $1620 to $2,600 a year, less a deduction of not to exceed 15 per cent as a measure of economy and a retirement deduction of 3½ per cent.

SERVICES AVAILABLE

A-205. Welder desires position. Attended Stevens Institute of Technology for two years. Fourteen years' experience in electric and acetylene welding of bridge, structural steel, boiler, tank and pipe-line work; also machine shop experience.

Statement of the Ownership, Management, Circulation, etc.

REQUIRED BY THE ACT OF CONGRESS OF AUGUST 24, 1912

OF JOURNAL OF AMERICAN WELDING SOCIETY, published monthly at Easton, Pa., for October 1, 1933.

State of New York } ss.
County of New York }

Before me, a Notary Public in and for the State and County aforesaid, personally appeared William Spraragen, who, having been duly sworn according to law, deposes and says that he is the Editor of the Journal of the American Welding Society and that the following is, to the best of his knowledge and belief, a true statement of the ownership, management (and if a daily paper, the circulation), etc., of the aforesaid publication for the date shown in the above caption, required by the Act of August 24, 1912, embodied in section 411, Postal Laws and Regulations, printed on the reverse of this form, to wit:

1. That the names and addresses of the publisher, editor, managing editor, and business managers are:

Name of — Post Office Address

Publisher, American Welding Society, 33 W. 39th St., New York, N. Y.
Editor, William Spraragen, 33 W. 39th St., New York, N. Y.
Managing Editor, William Spraragen, 33 W. 39th St., New York, N. Y.
Business Manager, M. M. Kelly, 33 W. 39th St., New York, N. Y.

2. That the owner is: (If owned by a corporation, its name and address must be stated and also immediately thereunder the names and addresses of stockholders owning or holding one per cent or more of total amount of stock. If not owned by a corporation, the names and addresses of the individual owners must be given. If owned by a firm, company, or other unincorporated concern, its name and address, as well as those of each individual member, must be given.)

American Welding Society, 33 W. 39th St., New York, N. Y.
F. P. McKibben, President, Black Gap, Pa.
M. M. Kelly, Secretary, 33 W. 39th St., New York, N. Y.
C. A. McCune, Treasurer, 25 West 43rd St., New York City.

3. That the known bondholders, mortgagees, and other security holders owning or holding 1 per cent or more of total amount of bonds, mortgages, or other securities are: (If there are none, so state.)
None.

4. That the two paragraphs next above, giving the names of the owners, stockholders, and security holders, if any, contain not only the list of stockholders and security holders as they appear upon the books of the company but also, in cases where the stockholder or security holder appears upon the books of the company as trustee or in any other fiduciary relation, the name of the person or corporation for whom such trustee is acting, is given; also that the said two paragraphs contain statements embracing affiant's full knowledge and belief as to the circumstances and conditions under which stockholders and security holders who do not appear upon the books of the company as trustees, hold stock and securities in a capacity other than that of a bona fide owner; and this affiant has no reason to believe that any other person, association, or corporation has any interest direct or indirect in the said stock, bonds, or other securities than as so stated by him.

W. SPRARAGEN, Editor.

Sworn to and subscribed before me this 21st day of September, 1933.

(Seal) MARY T. HICKEY
Notary Public, New York County, New York County Clerk's No. 170.

New York County Register's No. 4H244
(My commission expires March 30, 1934)

Building Up Pistons and Maintenance of Reciprocating Parts by Bronze-Welding

By T. W. GREENE

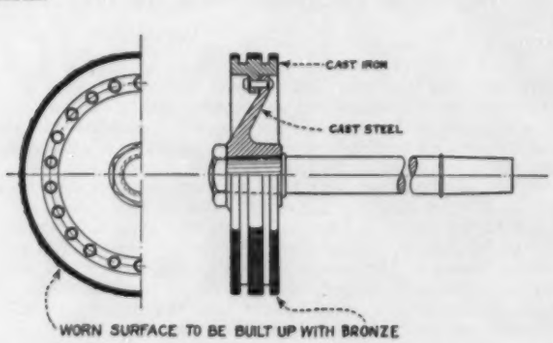
+Paper presented at Fall Meeting, A. W. S., Detroit, Oct. 2nd to 6th, by T. W. Greene, Development Section, Eng. Dept., The Linde Air Products Company.

Efficiency of Pistons and Similar Wearing Members Increased by Bronze-Surfacing with the Blowpipe

IN THESE days of stress and forced economy with maintenance expense cut to the minimum, any application which permits the maintenance of machinery in operation is welcomed, particularly if such applications not only economically salvage otherwise discarded parts, but by so doing actually improve their operating functions.

Bronze-welding by the oxyacetylene process for purposes of maintaining and increasing the efficiency of pistons, as well as other wearing parts of engines, pumps, compressors and similar reciprocating machinery, has certain features which should be extremely attractive to those responsible for cutting the cost of machinery and engine operation and maintenance.

Bronze-surfacing of pistons and moving parts is not a new application. One company operating a large number of compressors, sometimes under severe operating conditions, has resurfaced over thirty compressor cylinders over a period of several years with an estimated saving of several thousand dollars. In a number of other plants it has been standard practice for several years, but the opportunities for further profitable application of this method are so widespread that it seems important to re-emphasize this to industry in general.


CAST IRON
CAST STEEL
WORN SURFACE TO BE BUILT UP WITH BRONZE
BUILT UP SURFACE
RING GROOVES
SURFACE TO BE MACHINED AND EDGES TO BE ROUNDED TO 1/8" RADIUS

Sketch Showing Surfaces of Bull Ring Type Piston Needing Rebuilding

Heretofore new over-size cylinder liners have been required, or worn pistons have been scrapped, with resultant high maintenance cost. No infrequently new patterns have to be made and new parts cast to match the discarded ones, and while this is going on valuable time is lost. Obviously, all of this expense can be saved if some efficient means of reclamation is available. The bronze-welding process has proved to be the method. By an application of wear-resisting bronze-welding rod to the worn surface and machining to correct size, the part is new again with even greater efficiency than it had originally.

Advantages

The following advantages have been discovered by those who are now rebuilding pistons by bronze-surfacing:

1. The initial cost of reclamation is very much lower than purchasing new pistons, roughly, about one-third or one-quarter, including machining. An examination of cost figures for pistons rebuilt in one plant that has been utilizing the method for several years shows reclamation, including machining, at $15 to $25 against about $45 for a new piston of the 14-in. size. Four pistons, repaired by a large marine company which has recently taken up the work, cost in all $75, including machining. New pistons would have cost at least $350.

2. In many cases the saving in time is even more important than the initial saving. A piston that has to be replaced is frequently obsolete or is not carried in stock. This may mean waiting for a new pattern and casting. In marine work the tying up of a boat, it can be appreciated, is an extremely expensive matter. This is also quite true of much equipment in industrial fields.

3. Bronze-surfaced pistons or other parts give lower operating costs and greater efficiency while in use. In the case of the high pressure steam pistons in the marine field it is claimed that bronze-surfaced pistons save 20 barrels of fuel oil a day, worth about $20 at prevailing prices. This results from the use of rebuilt or surfaced piston rings, proper piston clearances and the minimizing of piston play, all of which help to cut down pressure losses.

The same is undoubtedly true to a great extent on compressors and pumps. The power consumption, compression ratio and over-all efficiencies are greatly increased through proper clearance of the piston in the cylinder.

4. The application of bronze-rebuilding has the advantage of maintaining high efficiency through proper maintenance. In many cases, because of the cost of replacement and loss of time, pistons are allowed to operate with excessive clearance, relying on the rings to do the work. They cannot then perform their own function properly. With a general knowledge of the use of wear-resisting bronze-welding rod much reciprocating machinery could be maintained to give greater efficiency.

5. Longer life with less wear and friction on the pistons and cylinder results from the use of bronze-surfacing.

The Scope of the Application

Many refineries in the oil industry have made a practice for several years of doing this work when rehabilitating their pumps and similar equipment. One of these companies has even gone further and built up some large rotary valves on a steam pump engine. There are also records of several diesel engine pistons reclaimed by bronze-surfacing with unqualified success.

The Bull Ring Resurfaced before Machining. This Saved Replacement and Cylinder Reboring

In the marine field, until recently, the work has been somewhat limited, but now certain shipowners, realizing the benefits from bronze-surfaced pistons and parts, have recommended to their maintenance departments that every opportunity be seized for rebuilding reciprocating machinery by the oxyacetylene bronze-welding process.

Factors Affecting Frequency of Replacement

Although as a rule the replacing of new pistons or the building up of old ones is a relatively infrequent operation, for an individual piece of equipment, when it is needed, any rapid and economical method is indeed valuable. The amount of piston wear, it can be appreciated, is influenced by many factors such as the service; whether the equipment is a prime mover or pump; the design, considering whether a tail rod to counterbalance the weight of the piston is part of the design; the position of the cylinders; the temperature of service; whether corrosive or erosive fluids are pumped; and the lubrication of the part. The amount of wear for some types and services is obviously greater than others.

Theoretically, most of the wear on pistons is expected to occur between the rings and the cylinder walls. Rings are replaced rather frequently, steam engine rings probably between one and four years, whereas a cylinder need not be rebored, or is not rebored whether it needs it or not, for possibly eight or twelve years. For compressors, however, where lubrication must be held to a minimum the wear is greater and replacements are more frequent. In this field particularly and for pumps handling corrosive and erosive liquids the renewal of pistons and similar parts is relatively frequent.

The Importance of Wear-Resisting Bronze

With the recent advent of the wear-resisting bronze-welding rod a surfacing material became available for general use which contains every essential requisite for bronze-surfacing work and accordingly should form a most decided influence toward making this rebuilding of worn and new pistons even more attractive than it has been previously.

This rod was primarily developed as a wear-resisting material for easy application with the blowpipe. Because the properties of the rod at the same time proved so desirable for joining work as well, it is now used universally as an all-purpose welding rod. Its use for building up worn surfaces, however, still remains its primary function.

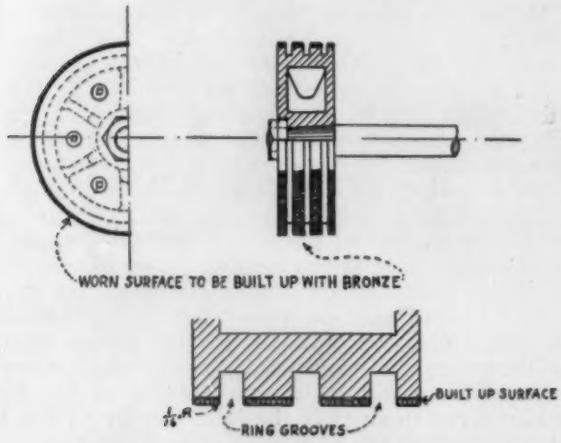
This rod, which may be classified as belonging to the manganese bronze series, contains in addition to copper and zinc in the 60–40 proportion commonly used for bronze-welding certain amounts of iron and tin. The presence of iron and tin causes the formation of innumerable small, hard particles called "delta" constituents evenly distributed throughout the bronze matrix. It is the presence of these hard particles which gives to the deposited metal its wear resistance as the hard particles serve to support the load thereby saving the matrix itself from excessive wear and giving it excellent bearing properties. The manganese and silicon in the rod minimize oxidation and gas inclusion, so that the deposited metal has a homogeneous structure free from porosity which can be machined even to a feather edge without holes or defects.

The hardness of this bronze-welding rod, 93–98 Brinell, closely approximates that of the gray iron that is frequently used for reciprocating surfaces.

Characteristics Affecting Certain Applications

Before discussing the bronze-surfacing procedure, there are two characteristics affecting the application which should be discussed. One of these is the physical property of bronze at high temperatures. Bronze begins to lose its strength at temperatures above 500 deg Fahr. For this reason, bronze-surfacing should not usually be applied to surfaces exposed to operating temperatures higher than 500 deg. Fahr. Temperatures higher than this are only found in industrial reciprocating equipment in exceptional cases and, therefore, this is not a serious practical limitation. Measurement of temperatures on Diesel pistons has shown that, although temperatures at the crown may be slightly in excess of 500 deg. Fahr., the temperature of the piston walls is not generally over

Rotary Exhaust Valves on Steam Powered Engine. Left to Right: Worn Valve, Resurfacing Valve and Rebuilt Machined Valve


WORN SURFACE TO BE BUILT UP WITH BRONZE
BUILT UP SURFACE
RING GROOVES
SURFACE TO BE MACHINED AND EDGES TO BE ROUNDED TO 1/8 RADIUS

Sketch of Typical Cast-Iron Hollow Head Piston and Surfaces to Be Rebuilt

300 to 400 deg. Fahr. even close to the crown. Bronze-surfacing for steam engines operating at 250-lb. gage pressure, equivalent to temperatures of 400 deg. Fahr. or slightly higher, has given excellent service.

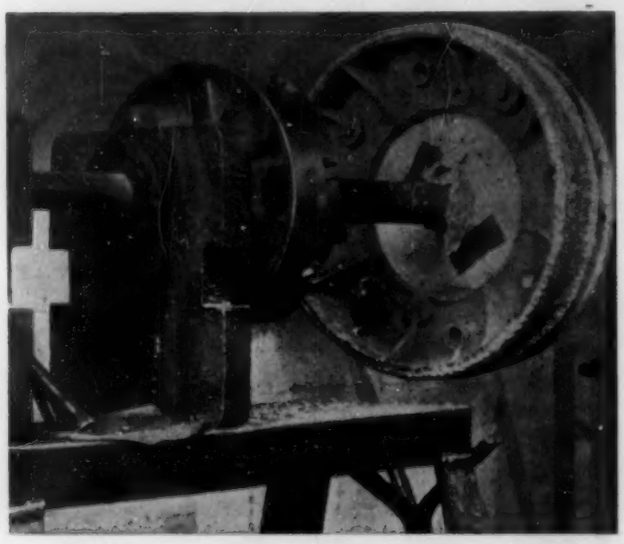
The second characteristic has been observed in cases where it has been necessary to reapply bronze weld metal a number of times on a steel surface. Under such conditions, there is a possibility that bronze weld metal may penetrate between the grains of the steel base metal while subject to the heat of rewelding to an extent which may cause surface checking of the steel. Therefore, bronze-surfacing should not be reapplied to built-up steel piston rods or other load-carrying steel parts subject to severe alternating and repeated stresses. It is important to emphasize that this penetration does not occur when bronze-welding is applied to cast iron and that consequently bronze can be reapplied as often as desired to cast iron.

The Resurfacing Operation

The application of wear-resisting bronze-welding rod is simplicity itself. Those who have used bronze-welding for general repair and reclamation work will find resurfacing work but slightly different.

Important Precaution.—If the work is to be done on a hollow piston head, the core plugs should be removed or a hole drilled into the cavities before welding in order to prevent the trapped gases from expanding and bursting the piston head.

The surface that is to be rebuilt must, if new or if showing but little wear, be machined or ground down sufficiently so that a layer of bronze can be applied. Surfaces that are worn will probably not need this preliminary work. Knowing that the bronze layer, provided it has been properly bonded, can be machined down to almost infinitesimal thinness, and knowing that the operator can limit the thickness of the bronze layer to at least $^1/_8$ in. and often less, it is a simple matter to calculate to what extent preliminary machining, if any, will be necessary. Preheating of the piston will probably not be essential, though if it is a large and complicated casting, welding gases can be conserved by doing so. The chill of cold metal, however, should be removed before welding and some preheating is always desirable. Preheating is also good for removing any impregnated oil in the surface of the castings. This must be removed, but a single rough machine cut over the surface to be rebuilt does the job well.



Rebuilt Piston in Position on Jig Made Specially for This Work

One of Six Hollow Head Cast-Iron Pistons Bronze-Surfaced with Splendid Results

Of vital importance are the flame adjustment and the flux to be used. A flame that is slightly oxidizing will permit much better bonding between the bronze and the base metal and should be used always. The correct oxidizing flame is obtained by first adjusting to neutral and then closing the acetylene valve on the blowpipe slowly until the inner cone has been reduced in length by about one-tenth. This flame should be checked periodically.

Two properties are required of a suitable flux for use with bronze-welding rod. At bronze-welding temperatures, the flux must unite with any oxides remaining on the base metal, permitting "tinning" to occur. By coating the weld puddle, the molten flux will dissolve the oxides of copper, zinc and tin that form in slight amounts and which might otherwise become entrapped in the weld metal, lowering its quality. It is desirable

that a liberal amount of flux be added continuously and where the rate of welding is rapid this can be done by heating the rod for a length up to a foot at one end and rolling it in flux spread in a long horizontal container. Flux adheres readily to a heated rod.

This application of the bronze-welding process to the rebuilding and surfacing of pistons, bull rings and similar reciprocating parts of pumps and engines is one which can be made to save the plant or ship sizable replacement costs. While the opportunity for doing this work ordinarily does not occur every day in any one plant, when a piston does need resurfacing it is obviously well worth while knowing about, because of the economy and other advantages of this process. Further than this, every maintenance department should be posted on how to do this work, because much time, labor and cost can be saved by utilizing the oxyacetylene process for bronze-surfacing pistons and other parts.

Welding of Commercial Yellow Brass Pipe and Other Non-Ferrous Piping

By **D. E. ROBERTS**

+Paper presented at Fall Meeting, A. W. S., Detroit, Oct. 2nd to 6th, by D. E. Roberts, Sales Engineer, The Linde Air Products Company.

WITHIN the span of a relatively short time we have seen the art of piping undergo a fundamental change. Welded construction has completely altered the economics and the engineering conceptions applicable to piping systems. Today, in our welding processes we enjoy a means of reproducing in a pipe joint properties of strength and corrosion resistance equal to, or better than, those possessed by the base material. Welding utilizes the full wall thickness of the tubing or piping and no added weight need be present to compensate for inefficient types of joints. Welding is motivating a trend in the design of tubular goods toward a more economical utilization of parent metal properties.

Welded Non-Ferrous Piping Is Establishing Enviable Record

We have observed the general acceptance of the welded steel pipe joint but not many of us appreciate the extent to which welding is employed in the joining of non-ferrous piping. The chemical and other process industries have pioneered in the application of welding to copper, brass, aluminum, monel, nickel and stainless steel piping, which plays such an important part in the safe transportation of corrosive fluids and gases, often at high temperatures. It is significant to note that welded non-ferrous piping has undergone a most severe test in these industries, where conditions of temperature, pressure, stress and corrosion combine to search out any weakness in the welded joint. With due consideration for base metal and filler material properties, welded joints made under proper procedure control in non-ferrous piping have established an admirable record of service performance.

Today, scarcely an important building structure is erected which does not incorporate some welding of non-ferrous piping. Brass and copper piping and tubing are practically universally specified for both hot and cold water services.

Boiler Coils of I. P. S. Copper Tubing Bent and Van Stoned by Use of Oxyacetylene Flame

The Tentative Code for the Fusion Welding of Pressure Piping, sponsored by the American Society of Mechanical Engineers with the cooperation of the AMERICAN WELDING SOCIETY, permits the bronze-welding of both copper and brass pipe.

An excerpt from the Proposed Building Code of the City of New York, under the Section on Joints and Connections in Plumbing Systems, reads as follows:

"Joints and connections for water or gas pipe made of brass, copper, black steel or black wrought iron, or combinations of these materials, may be made by welding."

Welding of Copper and Brass Pipe Permitted by Proposed New York City Building Code

The bronze-welding of brass piping has been standard practice with the Department of Hospital Maintenance, City of New York, for the past four or five years, and the results have been eminently satisfactory.

It has been the custom in some ship construction to bronze-weld the copper steam piping. Such systems have stood up well in spite of the excessive vibration to which they are subjected. Only recently a manufacturer of potash substituted a bronze-welded copper system for the transportation of liquid potash, accelerated corrosion tests having shown that there was no differential corrosion at the joint. The steel system previously installed lasted only two months under the severely corrosive action of the hot potash.

Thin-walled copper tubing has been very widely used in cold and hot water systems both with bronze-welded short bell-and-spigot joints and in combination with the

Van Stoning Copper Pipe on the Job Proved Both Economical and Practical

so-called sweat type fittings with which a low melting point solder is commonly used. Filler materials of higher melting point, such as silver solder and special bronze welding rod, may be also successfully employed in this type of construction. There are a number of installations of light-walled copper tubing in hospitals for conducting oxygen from manifold systems to various distributing points in the treatment and operating rooms. Several of these systems have been in operation for a number of years with bronze-welded short bell-and-spigot joints. No difficulty whatsoever has been experienced with these welded lines, which have remained permanently leak-proof and free from maintenance expense.

It is possible to cite innumerable examples where bronze-welded copper and brass piping systems for almost every conceivable type of service have stood up well and indicated the desirability of this type of joint.

Air conditioning, which is admittedly still in its infancy, promises to open up another very large field for the use of welded brass and copper piping. There is being constructed in New York City a Federal Court House building which will have a complete air conditioning system. Brass pipe in sizes up to 12 in. will be employed for the condensing and hot and cold circulating water. At the request of the successful bidder, the Federal Government at Washington, D. C., has given permission to bronze-weld this brass piping.

Bronze-Welding Most Practical for Brass and Copper Piping

The welding practices applicable to copper and brass pipe have usually been considered together, inasmuch as the same joint designs and procedures are recommended for each, with but slight exceptions. Joints of superior strength can be uniformly secured by welding with bronze rod—bronze-welding in the case of copper and most types of brass—fusion welding where the metal has a melting point as low as that of the bronze rod, such as in the welding of Muntz metal. Fusion welds are sometimes made in copper and higher melting point brasses, but special rods and welding procedures are required and there is little, if anything, to be gained. The evidence seems to point to the fact that a bronze-welded joint in red brass and copper meets the requirements of strength, and because of its reinforcement is adequate from the standpoint of corrosion resistance.

It is sometimes argued that filler material of the general type of 60–40 brass is not logically used in joining copper and red brass piping when the conditions of corrosion are such that these base materials are specified. From the standpoint of life, a properly made bronze-welded joint suitably reinforced and with sound, dense weld metal, such as is obtainable with special bronze welding rods, is, we believe, preferable to a joint in copper or red brass made with a rod approximating the composition of the base material, but because of its poor welding qualities may produce unsound or porous weld metal.

Joint Design

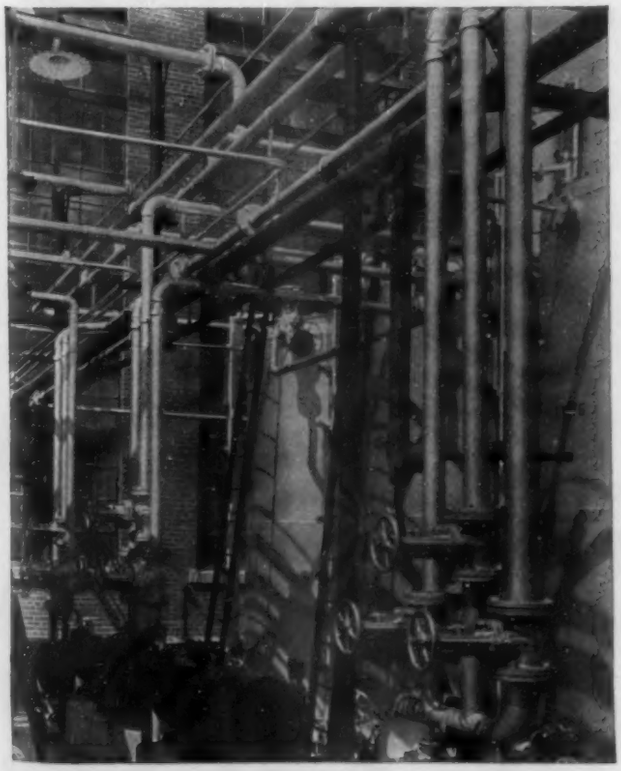
Early experiments in the application of bronze-welding copper and brass piping and tubing indicated the desirability of employing the short bell-and-spigot joint design, especially for vertical welds. This type of joint has been generally recommended for piping of small diameter. However, many entirely satisfactory installations have been made in brass pipe of large diameter and with heavier walls using the short bell-and-spigot design.

Van Stoning Aluminum Tubing. Previous Bursting Tests Proved That This Gives a Strong Joint

Silver Solder Was Used for Copper Sweat-Type Fittings for Medium Temperature Service

I recall one installation comprising the hot water system of a hospital, where 90,000 lb. of brass pipe in sizes up to 6 in. was installed, using the short bell-and-spigot joint and pre-fabricated brass welding elbows.

The advantages claimed for the short bell-and-spigot joint have been ease of welding, no projections or protrusions of weld metal on the inside of the pipe, weldability of the joints in various positions and development of full strength of pipe material. The open single vee butt type of joint, while satisfactory for rotating and horizontal fixed joints, seemed to offer difficulty in making a vertical joint due to the melting down of the upper edge of the joint with consequent undercutting of the pipe wall.



Process Piping and Equipment Economically Fabricated by the Oxyacetylene Process

In an effort to determine the best type of joint design for the welding of larger diameter brass pipe it was decided to conduct an investigation on 4-in. diameter brass pipe of standard I. P. S. wall thickness. Existing costs and tension test data had been limited to copper and brass piping and tubing up to $2^1/_2$ in.

Test to Determine Best Joint Design and Procedure for Large Diameter Brass Piping and Wall Thicknesses above $^1/_8$ In.

The test piping was commercial yellow brass, having the approximate composition of 67 per cent copper and 33 per cent zinc, with small traces of other elements. This is known metallurgically as alpha brass. The outside diameter was $4^1/_2$ in., the wall thickness $^1/_4$ in., these being the same dimensions as 4-in. standard steel pipe.

The joint design was of the open single vee butt type with the ends beveled to 45 deg. and a $^1/_{16}$-in. unbeveled portion at the inside wall.

An operator who has had experience in the welding of steel pipe and who is familiar with bronze-welding will have no difficulty in applying bronze-welding to copper or brass pipe. The welding of brass pipe demands nothing unusual in pipe welding technique. In this particular case the welding of yellow brass pipe of this composition, in which the melting point of the base metal so closely approximated the melting point of the bronze welding rod, required neither deep fusion welding nor true bronze-welding, the one essential factor being to break down the wall of the vee just sufficiently to insure positive sweating of the base metal in advance of the puddle. As in all bronze-welding a suitable flux was used.

Rotating welds offered no difficulty whatsoever, requiring only a little longer time to start welding because of the higher heat conductivity of brass as compared to steel. Puddling and manipulation of rod and flame are identical with steel welding using the forehand technique. Overhead welding likewise is easy and not at all complicated.

Welding of brass pipe in a vertical position is less easily accomplished, as is also true with steel pipe. It was formerly supposed that the bell type of joint would facilitate welding of vertical pipe, such as risers, because of the shelf supplied by the bell, but actual investigation has proved that the butt type joint can be as readily welded as the bell type in the larger diameters where the wall thickness is 1/8 in. and greater.

Welding Technique

A suitable technique is to deposit the metal in a sloping puddle, directing the flame upward so as to retain the molten metal, at the same time manipulating the rod in the puddle to prevent excessive melting of the upper half of the joint and to solidify the puddle in even ripples. For the investigation our No. 25 M bronze rod was used and gave satisfactory weld strength and quality with freedom from porosity, blowholes or other defects. The welding was done with a slightly oxidizing flame, this being desirable as a reducing flame causes excessive boiling.

Test data showing rod, oxygen and time for welding 4-in. pipe joints in various positions are given in Table 1. Time for welding with pipe in a fixed horizontal position,

Bursting Test on Aluminum Tubing with Shop-Made Van Stone Flanges. The Specimens Have Been Cut to Remove Flanges and Tack-Welded for Photographing

requiring overhead welding on the bottom, is influenced far more by the skill of the operator than the question of the weldability of the brass material.

Table 1—Test Data—4-In. Std. I. P. S. Brass Pipe

Open Single Vee Butt Type Weld—90° Vee

Weld No.	Type of Weld	Welding Rod,* Lb.	Oxygen,* Cu. Ft.	Welding Time,* Min.
A	Rotation	0.39	4	9 1/2
B	Rotation	0.44	3	8
C	Rotation	0.43	4	12
Average		0.42	4	10
D	Vertical position	0.39	3	8 1/2
E	Horizontal position	0.44	3	12

* All data given are for actual welding of joint only and do not include tack-welding. All joints were tack-welded in three points with a spacing of approximately 1/2 in. before tack-welding, leaving about 1/16-in. spacing after tack-welds had cooled. Rod used was 3/16-in. diameter. Tip aperture size was equivalent to a No. 45 drill size on a low pressure, injector type blowpipe.

The test data given in Table 1 do not show much difference between rotation and position welding but this was due to the work being done in the most convenient position, a condition rarely found on the job.

Test Results

The tension tests of coupons cut from the butt joints in various positions are given in Table 2.

Table 2—Tension Test Results

Coupons Cut from Butt Type Joints in 4-In. Std. I. P. S. Brass Pipe

Weld No.	Type of Weld	Welding Time, Min.	Tensile Strength of Coupons, Lb. per Sq. In.	Fracture*
A	Rotation	9 1/2	38,200	Weld and pipe
			35,100	Weld and pipe along scarf
B	Rotation	8	35,800	Weld and pipe near scarf
			34,100	Weld and pipe near scarf
C	Rotation	12	42,000	Base metal 3/4 in. from weld
D	Vertical position	8 1/2	35,400	Base metal and scarf
			39,300	Base metal
			32,500	Base metal near scarf
			39,000	Base metal
			34,000	Base metal near scarf
			37,600	Base metal near scarf
E	Horizontal position	12	32,000	Along scarf, small lap
			32,100	Base metal near scarf
			33,600	Base metal near scarf
			35,300	Base metal near scarf

* Most of the specimens failed in the base metal near the scarf; this is believed to be due to stress influence set up at this point by the stronger and harder weld metal, where the softer base metal started necking down at the point of failure.

It will be noted that the strength of the annealed brass pipe, approximately 32,000 to 42,000 lb. per sq. in., was obtained in all the tests.

In Table 3 is given a comparison between the time and materials required for welding steel and brass pipe. A conservative estimate may be taken on the basis that the welding time and oxygen required for welding brass pipe are about 15 per cent less than for steel where forehand technique is employed, the rod requirements being practically the same. For vertical and horizontal joints, the data should be multiplied by the factor 1.4.

Table 3—Welding Rates and Material Consumption for Steel and Brass Pipe

Forehand Technique—Rotation Welding—90° Vee

Brass Pipe Equivalent in Wall Thickness to Steel Pipe

Nominal Size of Pipe	Pipe Wall Thickness, In.	Steel Pipe: Welding Time, Min.	Steel Pipe: Oxygen, Cu. Ft.	Steel Pipe: Welding Rod, Lb.	Brass Pipe: Welding Time, Min.	Brass Pipe: Oxygen, Cu. Ft.	Brass Pipe: Welding Rod, Lb.
2	5/32	6	2	0.2	5	2	0.2
2 1/2	3/16	8	3	0.25	7	3	0.25
3	7/32	10	4	0.3	8.5	4	0.3
3 1/2	7/32	11	5	0.35	9.5	4.5	0.35
4	1/4	13	6	0.4	11.	5.5	0.4
5	1/4	16	8	0.55	13.5	7	0.55
6	9/32	21	12	0.8	18	10.5	0.8
8	5/16	29	20	1.1	25	17	1.1
10	5/16	37	33	1.7	32	28	1.7

Bell and Spigot

Previously published data have advocated a short bell-and-spigot joint for gas-welding brass pipe. In the smaller sizes on which tests had been made results indicated

more satisfactory welding conditions and better physical joint properties.

Belling of the pipe is not difficult. In general, on light wall pipe the pipe end is first annealed by heating with the blowpipe, and then a pin machined to the proper taper is driven into the pipe end. The method used on the 4-in. brass pipe with 1/4-in. wall was to take a slotted bar having a sufficient lever arm and crimp the edge of the pipe outward in short bites, going around the circumference several times so that the I. D. of the bell was equal to or greater than the spigot. One man can readily do this under field conditions in 10 to 15 min. on 4-in. pipe size with a wall thickness of 1/4 in. With greater wall thickness considerably more difficulty would naturally be experienced.

Welding data for making bell-and-spigot joints in the fixed vertical and horizontal position are given in Table 4. It will be seen that the welding time, oxygen and rod required were 50 to 100 per cent greater than in making the butt joints in similar positions.

Table 4—Welding Data—4 1/4-In. Wall Brass Pipe

Bell-and-Spigot Joint (30-Deg. Bell)

Weld No.	Type of Weld	Rod,* Lb.	Oxygen,* Cu. Ft.	Time,* Min.
1	Vertical position	0.49	4	11 1/4
1 (Special bell)	Vertical position	0.78	7 1/2	18 1/2
2	Horizontal position	0.52	6	17 1/2

* All data given are for actual welding of joint only and do not include tack-welding.

All joints were tack-welded at three points. Rod used, 3/16 in. diameter. Tip size No. 8 (W-17).

It is extremely difficult to evaluate the strength of the short bell joint because coupon tests induce decided bending moments which tend to tear off the end of the bell at the edge of the weld. To compensate for this, a backing-up strip of 3/8-in. plate was clamped to the specimen to minimize bending. Comparative tension results were not possible because of the eccentricity of the bell-and-spigot joint, but such tension tests as were made showed that the butt welds were the stronger by a good margin.

Since joint preparation and welding costs for short bell-and-spigot joints differ little from those for the butt type in the smaller diameters, and because line-up and tack-welding are simpler, the bell type of joint may be found as practical as the butt type for sizes where the wall thickness is 1/8 in. or less. Previous tests on full section specimens have shown that weld strength in the smaller diameters is quite satisfactory.

Conclusions

1. Although the full strength of the short bell-and-spigot joint in brass pipe cannot be obtained except by test of a full pipe joint, it is believed that because of the reduction of the wall thickness in belling and other factors, the bell-and-spigot joint is not as efficient as the butt joint. Especially is this true in the larger pipe sizes and where the wall thickness exceeds 1/8 in.

2. Inasmuch as the cost of the bell-and-spigot joint, both in welding and preparation, is greater than the plain butt type for the larger diameters, it is recommended that the butt type joint be used for all brass pipe having wall thicknesses in excess of 1/8 in.

All Aluminum Elbows under 6-In. Diam. Were Welded Miter Turns

Welding in the Automotive Industry

By CLAUDE A. BOWLUS

†Paper presented at Fall Meeting, A. W. S., Detroit, Oct. 2nd to 6th, 1933 by Claude A. Bowlus, Development Engineer, Welding Sales & Eng. Co.

THE development of the automotive industry owes much and has contributed much to the welding art. The use of welding has vastly reduced the cost, improved the appearance and reliability of laborious fitting operations on bodies, made possible reductions in weight of materials required, joined tubes to forgings, expeditiously fastened sheet metal to light stamped structures at practical expense and greatly increased the useful life of the chassis as well as the body with attendant comfort to the owner. We will discuss the application of the various processes of welding as applied to the automotive industry.

Forge Welding

It is very doubtful if forge welding has at any time ever been extensively used in the production of automobile parts. It is true that body irons and trim rails, occasionally body brackets, and a few parts in which breakage would not occasion hazard to life or limb may have been forge welded. There originally existed such a degree of prejudice against welding that intricate parts were usually machined from solid stock rather than risk breakage in the weld; expense was not spared to produce such parts in drop forge dies. Also with the wider application of alloy steels, welding was regarded even with less favor and its use awaited the development of processes better adapted to the needs of the industry.

Acetylene Welding

The combustion of oxygen and hydrogen originally was depended upon for the high temperature necessary for welding, but acetylene has now become the principal fuel for torch welding except in a few isolated cases such as lead burning for batteries. Acetylene is lower in cost, can be readily produced from carbide, can be dissolved in acetone, thereby keeping down the high pressures in the container, and yields the higher temperature. Furthermore the white cone visible in the flame of an acetylene torch is much more easily adjusted to the proper value than in the case of the almost colorless hydrogen flame and the scale formation on the surface around the welded area favors the use of acetylene especially on steel parts.

Acetylene welding has been used in the automotive industry very extensively since the advent of the steel body in 1914 and has found wide use on chassis parts even prior to that date. Forging operations were frequently supplemented with acetylene welding and a vast amount of brazing with the acetylene torch was done on fenders, oil pans, frames, axles, windshields and miscellaneous small parts. In fact the attainment of quantity production would have been almost impossible without the acetylene welding torch.

During the War, steel tubing welded with the multiple tip torch as the sheet stock issued from forming rolls with the seam closing under the heat of the torch came to be widely used. Such tubing was made of full finished stock and could be passed through further simple operations that developed a finish suitable for plating, enamel or paint. Such tubing has the inner and outer diameters concentric, making it especially desirable for propeller shafts. The cost has been favorable as compared to seamless tubing. Production as high as 25 ft. per min. of tubing with a $^1/_8$ wall thickness is readily attainable with a comparatively simple and inexpensive equipment.

Automatic machines with spark plug ignition and electrically controlled gas valves have been applied in some cases to jobs particularly adapted to acetylene. With the multiple tip torch properly adapted to the contour of the work, such machines should be capable of very nice refinements. In view of what has been done with tubing, it would seem that the production possibilities of such machines have not been extravagantly exploited.

Heavy sections cut from cross-rolled plate with the pantograph cutting torch and arc welded together are being extensively used for jigs, fixtures, bedplates, die blocks and frames for heavy punch presses. Shapes formerly forged from large bars of round stock are now more easily and cheaply obtained cut from cross-rolled steel plates of the requisite thickness. The saving in cost and weight is important, but the saving in time is such that frequently a heavy structure can be built ready for machining more quickly than patterns can be made for such parts of cast iron.

The equipment used for modern acetylene welding is thoroughly standardized. Containers of oxygen and acetylene are carefully made and thoroughly tested. Reducing valves have been developed with high factors of safety and coupling devices are so designed that regulators intended for oxygen cannot be used on an acetylene or hydrogen tank. There is a tip size suitable for almost any sheet metal weight down to 24 U. S. gage. The valve seats of modern pressure regulators are made with seats renewable at small cost, parts are accessible with very simple tools and a man can readily be trained to rebuild and condition almost any regulator on the market. Attempts have been made to carry out such repairs in the plant but the low cost of repairs in local service shops in this area and the durability of the modern equipment have contributed to make the practice unprofitable, except in a very few cases where a large number of torches are in use.

It does not seem that acetylene welding has suffered materially with the advent of other methods, rather the field of the acetylene torch has been extended with supplementary possibilities that have come with the further development of automotive parts to welded design.

The precision with which parts may be cut to shape with the acetylene cutting torch has suggested some very unusual possibilities. It may be that in the near future ring gear blanks will be acetylene cut and with gear teeth roughed out with the new process of flame machining which seems to offer obvious means of cost reduction.

Electric Butt Welding

Electric butt welding had its inception almost concurrently with the automotive industry. The actual application of butt welding awaited the time, however, when automobiles were produced in large quantities because the electric butt welder is essentially a quantity production tool. Naturally the radical reduction in cost envisioned by the process leads to some applications, such as brake rod and clevis assemblies, in which breakage occurred with serious implications to automobile drivers. It was discovered that annealing of the welded

parts prevented most of the trouble and considerable saving in cost was effected nevertheless.

Probably one of the most important applications was the welding of wheel fellies and demountable rims. Breakage at the weld was overcome by properly timing the cut-off of current at the completion of the weld, a slight dwell in the current generated enough heat in adjacent areas that the weld did not cool too rapidly. There developed the theory that the strongest portion of the rim was at the weld and pains were taken in some shops to locate the valve stem hole at that point, so it is apparent that earlier troubles from breakage were corrected with wider knowledge and more careful control of the heating current. Other early uses included the salvage of tools, joining of tubes to forgings for propeller shafts and torque tubes.

Butt welding as originally contemplated was based upon the principle of flowing electric current from one mating part to another until the metal reached welding heat, at which time the upsetting and welding pressure was applied and the current cut off. It is a theory of this author that the pressure of hammering or upsetting in the butt welder actually lowers the melting point of steel in the same manner that pressure lowers the melting point of the ice packed in a snowball. With the pressure there was an appreciable thickening of the section at the weld which added considerable rigidity to the section, and the criterion of a good butt weld was the ability of the weld to hold in test beyond the strength of either of the mating parts. In case the pressure was applied unevenly, or at too early a stage, the parts froze frequently at the joint so that the transformer was likely to be overloaded and burned out.

In the more modern method of flash welding parts may be very poorly mated, in fact it is of advantage to have a slightly irregular fit, because the mating parts are fed together gradually only as the heavy current practically blasts away the excess metal until mating faces actually mate evenly while the heat runs back to bring the entire area of the faces of the parts well in the range of welding heat, after which the upsetting and welding pressure is applied exactly as in ordinary butt welding. Flash welding is more economical in power consumption and is no doubt more reliable, but the fine spray of molten metal from a flash weld forms a coating on adjacent areas that is hard to remove and is objectionable in some applications.

To meet the requirements of larger production fully-automatic machines driven by motor and cam, or oil gearing, made their appearance soon after the War, and production as high as six thousand welds in nine hours on wheel rims and similar material was attained. The automatic machine made possible the welding of mated stampings of number 20 U. S. gage body sheet to form the shroud in 1923. In the next three or four years practically all separately applied molding disappeared from automobile bodies. In the latest practice the side panels with door openings stamped out and reinforcing metal spot welded in place are welded to the rear panel from roof rail to sill on heavy-duty double end machines equipped with air or hydraulic clamping devices, automatic push-up, upset and cut-off cams, at a production rate approaching one assembly per minute. The parts are jigged to form accurate assemblies, the flash is removed by grinding or broaching and the clamping dies are so accurately aligned that a finished sedan, roadster or coupe body outer surface is a one-piece unit. This has eliminated streaks of rust coming from under overlapping sheets of metal and made possible an unbroken surface upon which to apply coats of primer and lacquer.

The limit of butt welds on thin gages seemed, until recently, to rest at about 120 in. to keep the transformer within single-phase capacity, but multiple transformers have been used on some large machines in the light of which it is apparently possible to go much beyond any immediate requirement. On heavier stock than about three-sixteenths with long seams it has been necessary in some cases to use three-phase driven single-phase generators to avoid the heavy surge on primary power lines. Butt welding units are being operated in that manner in which the peak load is around 2000 kv-a. for axle housings and around 6000 kv-a. on multiple transformers for pipe welding—not, however, for the automotive industry.

Clamping dies were at first made from cast or rolled copper, later of harder copper alloys—in some instances of aluminum bronze. The choice lies somewhere between a die hard enough to resist deformation with frequent clamping and an alloy of the proper analysis for the required conductivity. One or two local foundries have had considerable success with special alloys for this purpose.

In general about three-sixteenths of the length of each mating part is used up for flashing and upsetting in the case of cold-rolled steel below $^1/_2$ in. in thickness. Mating parts are preferably not trimmed accurately to present evenly abutted faces, but rather the flashing should take place at varying positions so that the entire capacity of the transformer can readily blast away any areas disposed to cause freezing and the inclusion of any oxides or slag in the finished weld. The voltage between transformer terminals varies from two to six, depending on die fit and interval of separation of the dies.

There is apparently no entirely satisfactory formula for determining the size of transformer for a given area to be welded. Competing manufacturers vary widely in their rating and recommendations so that machines are usually purchased on a guaranteed performance basis.

Spot Welding

Spot welding in the automotive industry has been widely used on all sheet metal parts since about 1912. Steel bodies in 1914 were riveted, not welded. Spot welding had been mostly confined to fenders and chassis sheet metal parts. Capacities of welders have not varied much from the limits of 5 to 35 kv-a. Vast improvements in efficiencies and mechanical arrangements have been made. Automatic cam-operated machines with speeds as high as 200 spots per minute were introduced about ten years ago but mainly spot welding has been done by the hand- or foot-operated machines until recently. During the past three or four years a machine consisting of a suspended transformer with water-cooled flexible leads to an air operated welding head controlled by a trigger grip has been widely applied to bodies and other parts too bulky to be handled readily or in positions inaccessible to the stationary unit. Such machines are especially adaptable to conveyor lines; their performance is reliable and marks a distinct advance in the application of spot welding.

High production requirements and floor space limitations have demanded practically uninterrupted service of the spot welder. Contactors have come in for much study, and automatic timing of the spot is being successfully accomplished with vacuum tube control and other very ingenious devices. Such developments have raised production capacity and effected great improvement in the quality of the spot.

Spot-welder points, which are the principal wearing parts and have to be frequently renewed, were formerly

made in the tool room as required. A number of methods formerly used to couple the point to the current conductors have been largely abandoned in favor of a small renewable tip made in Detroit shops and fitted into an adaptor at the end of the conductor by a Morse taper fit. The pressure of the welding operation maintains a tight fit and leaky water lines are the exception rather than the rule today. Another method extensively used on stock up to $^1/_8$ in. thick consists of a water-cooled body with a straight length of special alloy $^5/_8$ in. diam. fed up through the body as required. The material from which such renewable tips are made is preferably a hard-drawn alloy copper of high conductivity, special work-hardening quality and wear resistance. This quality in the latest type of point partly eliminates frequent filing of the point by the operator, insures the diameter of the spot being maintained more nearly constant and the quality of the weld held to satisfactory commercial limits.

The accepted standard of a properly welded spot requires that the spot shall tear entirely out of one sheet when the two sheets are torn apart. Prolonged duration of the welding current causes indentation of the points into the metal, thereby reducing the areas of effective metal forming the joint. Proper current control and point set-up correct this difficulty. In the case in which indentation of the point is objectionable, as in body welds, a broad flat tip is used on one side with a bullet nosed tip on the other. The indentation is confined to one side in this manner. Laminated faces on points have been used also for the same purpose.

Projection or Relief Welding

Quantity production of parts such as metal running boards, brake shoe assemblies, axle dust washers and other large production assemblies, suggested the possibilities of making a group of spots at a single stroke of a heavy-duty spot welder, hence the revival of the earlier developed art of projection or relief welding. In this process the mating parts are fitted together approximately to the final position but separated slightly by a number of small projections embossed preferably in the thicker piece of the two mating surfaces. The mating parts are pressed together between heavy electrodes connected to the terminals of a transformer secondary. The current is confined to the surfaces in contact when applied for a predetermined interval to bring the projections up to welding heat, the pressure is suddenly increased and the current is cut off. A slight dwell of the heavy pressure allows the fused metal to freeze, the die raises and the operation is complete. Sheets as heavy as $^1/_4$ in. may be readily embossed and projection welded.

Pilots may be used in perforated holes, clamps may be applied at the edges and other means applied so that pairs of mating parts can be thrown rapidly into the machine, and by hand feed as many as 350 assemblies per hour can be welded. Automatic feed and magazining of parts has, in many cases and might in many others, greatly increased this figure. Frequent change of models in the automotive industry, however, has prevented the highest development of automatic feed.

Machines originally designed for projection welding for the automotive industry were not built to the highest machine tool standards but were adequate to greatly reduce costs and mark a genuinely important development, although the principle and application of projection welding has been known and applied in other lines several years before. The first important application in the automotive industry came about in 1927. Since that time heavy, ruggedly built machines up to 500 kv-a. have become commonplace. In one or two cases three-phase transformers have been used to balance the load which has gone beyond normal single-phase capacity. The development of projection or relief welding machines is approaching the limitations of single-phase capacity and larger units will likely await the application of three-phase driven single-phase motor generator sets.

The height and area of projection to be used are not determined by any generally accepted formula. It is more important to have the group of projections for any weld of uniform height. Also there seems to be a limit to the number of projections that can be included in a given area. Rarely can over twelve spots distributed over 60 sq. in. of area be readily done without considerable trouble or a very heavy machine.

The design of dies or electrodes is important in projection welding. In some cases guide pins with insulating bushings will greatly help in holding the alignment of mating parts. Such insulating bushings have to be securely anchored into the die to prevent sticking to the pin which heats up with the current in the stray magnetic fields around conductors of heavy alternating currents. The area of the die adjacent to the projection indents badly and the dies should preferably be so designed that a finishing operation will restore the surface. Hard alloy inserts help in some cases. A very satisfactory die in one case was built up with a copper die shoe above and below with a renewable copper contact surface cast accurately to shape with water-cooling passages of steel pipe cast in, and with hold-down bolts so arranged that contact surfaces could be changed in about fifteen minutes. The cost was much lower than in the case of a solid block of hard-rolled copper that had to be machined to shape. Alloy copper with work-hardening qualities, high metal hardness, as well as high conductivity, seems to offer some possibilities in this respect.

Seam Welding

Seam welding was originally applied to body seams which were afterward filled with solder before the wide use of butt welding. This process has since been more widely applied to gasoline tanks and mufflers. The necessity of using a circuit interrupted at timed intervals causes the finished weld to present a surface that cannot readily be finished in an acceptable condition for priming and paint. Consequently seam welding is usually confined to parts in which the welds can properly be left unfinished.

The seam welder rolls are preferably made of special copper alloy with work-hardening properties to avoid frequent refinishing inasmuch as the maintenance of proper operating conditions requires the rolls to present a uniform width in order to secure nearly constant current density for the weld. The width of the seam must be chosen of such a value that the pressure does not cause the roll edges to upset and widen too rapidly. This difficulty has been overcome in some cases by driving the rolls with knurled driving surfaces disposed on either side opposite from the work and minimized to some extent by freely flowing cooling water over the work while welding.

Vacuum tube controlled circuit breakers and other devices have been developed to accurately interrupt the current at timed intervals. The Thyratron tube control has made possible as high as 1800 intervals of welding current per minute. This precision control has widened the application of seam welding considerably and also helped to some extent in the quality of weld such as may be required for pressure tight containers.

The seam welding machines now available present a vast improvement over the original commercial machines

of about 35 kv-a. capacity imported from Germany shortly after the War. For modern requirements in which the latest circuit breaking equipment is used, it has been necessary to build transformers up to 200 kv-a. nominal rating to meet the demands of quantity production, likewise the modern seam welder shows great refinement in design and the tool standards to which it is built.

Tubing

The production of tubing for the automotive industry includes processes of welding with acetylene, high cycle current, metallic and carbon arc, direct current, electric roll seam, butt welding and atomic hydrogen. The merits of the processes are subject to wide variation in quality and cost of production but there is available satisfactory welded tubing for any requirements from muffler pipe and robe rail to propeller shafts.

Electric Arc Welding

Electric arc welding was used in the automobile shops to some extent immediately following the War for maintenance and repair work. The first production application of metal arc welding in the automotive industry was a battery of semi-automatic machines for welding axle housings. These machines were supplied with current from transformers transmitted to semi-automatic weld heads equipped for hand feed to use 1/4-in. electrodes covered with paper impregnated with flux—the forerunner of the modern shielded arc wire.

At about the same time the automatic metallic arc-welding head was developed and first adapted to special machines for rotating the work under the arc, one head only at first, later as many as four heads operating on a single assembly. Propeller shafts, which had formerly been satisfactory with forging counterbored to present an abutting face with and butt welded to tubes, had been satisfactory, but higher road speeds required more accurate balance and arc welding made it possible to pilot a machined shank of the forging into the tube to assure alignment after which the assembly was completed with an arc-deposited fillet weld.

In applying the automatic arc to the propeller shaft job it was found that the arc would be enclosed from neighboring machine operators so that arc welding could be done progressively in a production line. The saving of the automatic over hand operation gave considerable impetus to such equipment and shortly after there were several large installations in which rear axle housing seams were welded by this method. There followed applications to frame cross members, front axle spring pads, generator cradles, wheel hubs, mufflers, shock absorbers, truck wheels and many small parts.

By far the greater portion of the arc welding has been done with the metal arc although some applications have warranted the use of the carbon arc in which adjacent areas of parent metal are fused to form the weld. There has been developed also a carbon arc-welding head with special features for shielding the arc by means of a twisted paper rope impregnated with an autogenizer which to some extent excludes atmospheric oxygen and partly insures a weld area free from oxides and intrides. Some applications of this process have been made, particularly on axle housings and wheel hubs. The arc is inclined to shift somewhat from a regular path as in the case of the metal arc without special provisions which are readily applicable to the latter; but in cases in which there is an ample factor of safety and to which the equipment is properly adapted little objection has been found to the carbon arc.

Alternating current transformer with special winding and stabilizing devices has been used especially for the repair of cast-iron cylinder blocks with a variety of special filler rods. Cylinder bores can be repaired in the case of sand-holes and scores by thoroughly cleaning the cavity and filling in with a nickel alloy rod with an arc of eight to twelve volts and frequently peening down the deposited metal. After repair the bore can be honed to a full finish with satisfactory results.

Welding wire used for acetylene welding was not in all cases readily applicable for the arc process. Chemical analysis alone was not a reliable guide. Trial and error methods pitted against back door salesmanship made some progress. Specifications were at first obsolete almost as rapidly as adopted. Gradually some definite principles of welding wire manufacture were established in the automotive industry and today practically all welding wire is bought on chemical analysis and performance specifications. The carbon, phosphorus, sulphur, silicon and manganese content are required to be carefully controlled. Special purpose electrodes for uses other than on steel are still subject to considerable discussion and development, but bare or processed arc-welding electrodes of reliable performance are readily available.

The flux coating for automatic use stabilizes the arc to a considerable degree, shields the arc in part from oxides and nitrides and greatly increases the deposition speed and efficiency. The development of fully shielded arc rod has now made possible an arc deposit superior to most deep drawing steels such as enter into frames and other stamped or formed members. The rate of deposit by hand in lineal feet per minute compares favorably with the automatic metal arc-welding machine. There has been developed within recent months a welding head adapted to feed the fully shielded arc rod and in the light of present development we can safely predict the application of arc deposits on fully automatic machines superior to the metal from which frames and body stamping are being fabricated. It is not impossible that frames and other parts will be welded automatically and the use of riveting will be entirely superceded by combination of various method, or a single process of welding.

Atomic Hydrogen Welding

Atomic hydrogen welding in which the arc is shielded by a blanket of hydrogen gas has not met with very wide application as yet because of its more recent inception and greater cost as compared to the automatic arc. The hand-operated atomic arc is rather generally known and is being used with excellent results for building up die surfaces.

There has been one application in which fender stampings are being welded together in special clamping jibs. This method of welding was chosen because the edges of the metal could be flowed together in a joint that could be power hammered and finished to a surface uniform with the parent stock producing a welded area that is free from blow-holes or porous spots and can, therefore, be satisfactorily covered with enamel.

One manufacturer of automotive parts is utilizing the automatic atomic hydrogen welding head in the production of welded tubing which is processed to form a rear axle housing. The weld withstands severe forming operations without failure and the appearance of the finished product is exceptionally favorable.

The atomic hydrogen process possesses some distinct advantages that commend themselves to the automotive industry. The resultant weld is free from scale, the weld is more reliable than any other and may be applied

to almost the entire gamut of alloy steels with the assurance that a weld can be produced as strong as the parent stock. The cost of operation is above that of the metal or carbon arc but this process should find extensive application on products to which other processes are not applicable.

Thermit Welding

Thermit welding has not been used to any extent in automotive production except for occasional punch-press crank-shaft repair and such allied operations, inasmuch as its application is limited to comparatively heavy sections.

Summary

The high road speeds, the extended uses of alloy steels and the latest curves of advanced streamline design have not exacted any requirements that have not been progressively met with the available processes of welding, and the gossip of the engineering lobby does not predict any radical departures from present manufacturing practice that will not be promptly met with the enthusiasm that has been brought to bear with such applications of the past fifteen years.

The Welding of Inconel

By F. G. FLOCKE, J. G. SCHOENER *and* R. J. MCKAY

†Paper presented at Fall Meeting, A. W. S., Detroit, Oct. 2nd to 6th, 1933, by F. G. Flocke and J. G. Schoener, Development and Research Department, and R. J. McKay, in charge of Technical Service, International Nickel Company, Inc.

THE development of the new alloy, Inconel, has been contemporary with progress in the welding industry. At the same time as the properties of this alloy were being studied, advances in the speed and facility of welding, and the strength and soundness of welds were being announced. It was thus natural, as well as necessary, that welding facility should be one of the principal criteria determining whether this composition deserved launching into competition with the many other good corrosion resisting alloys.

Some research was necessary to develop proper fluxes for electric welding and determine the proper procedures for oxyacetylene welding. It was found in this research that the welding characteristics of the metal were satisfactory, that suitable rods and welding methods could be used and welds made with ease combining physical and corrosion resisting properties which compared favorably with those of the parent metal. To obtain this welding facility it was not found necessary to change the composition of either parent metal or welding rod from that desired for the best physical and corrosion resisting properties. Heat treatment was not found necessary and the heat effects of welding not deleterious.

Inconel is fundamentally nickel to which sufficient chromium has been added to make it non-tarnishing in any form or finish, and since ferro-chromium is used in making this addition some iron is present. The analysis is 80% nickel, 14% chromium, 6% iron.

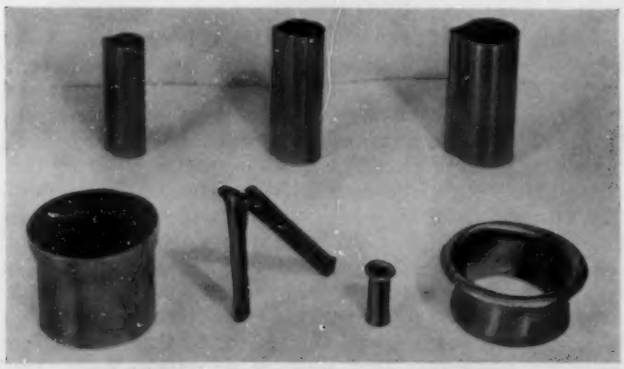


Fig. 1—Ductility of Inconel Gas-Welded Tubing. Note the lip tubing and the ductility of the gas welds.

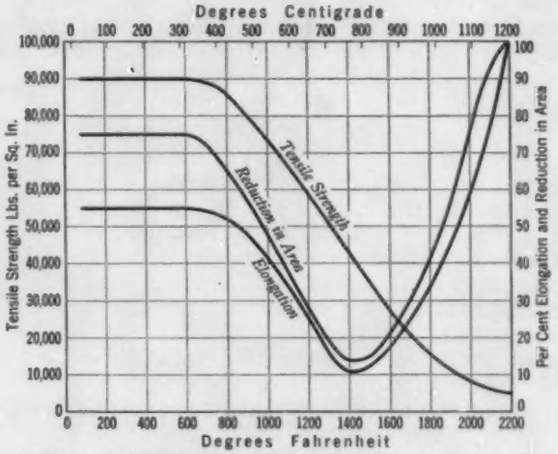


Fig. 2—Curve of Tensile Properties of Annealed Inconel at Elevated Temperatures

This alloy originally introduced and intended for use in the dairy industry has been used in the construction of holding and storage tanks, vats, coolers and regenerators. Its adaptation in that field indicated a certain usefulness in the food and canning industries, in which fields it has been used as steam jacketed kettles and cookers. A relatively high interior finish, as well as a corrosion resistant surface, is required here as in the dairy field. The high strength and ductility with high impact value, high modulus of elasticity and strength and resistance to oxidation at high temperatures have led to introductory uses in such widely separated fields as nitriding boxes, tube or sheet coverings for domestic range-heating elements, airplane exhaust manifolds, screen wire, textile machinery and brewing and distilling equipment.

For all these uses Inconel is available in the usual commercial forms as sheet, plate, strip, rod, tube and pipe, both seamless and welded, forgings and special shapes.

To make satisfactory joints in a variety of shapes and gages and under practical shop conditions welds must meet a number of different requirements. The present discussion has been shaped to take up these several requirements in order, as follows:

1. Weldability
2. Strength
3. Ductility
4. Soundness
5. Weldable thickness range
6. Finishing welds
7. Ease of repair
8. Corrosion resistance of welds

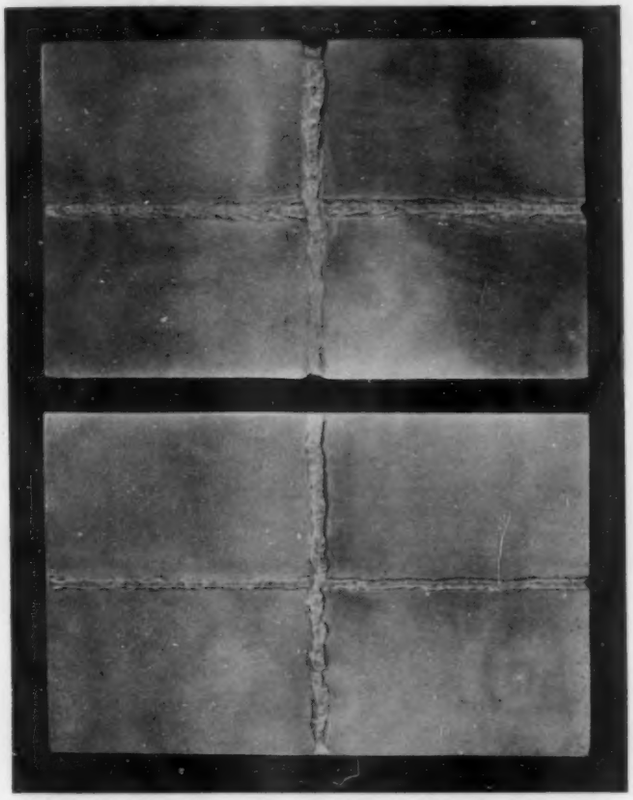


Fig. 3—Metallic Arc Weld on 1/2-In. Thick Inconel Sheet, Welded from One Side. The complete and uniform penetration is to be seen in the lower photo.

1. Weldability

Inconel can be joined by all the commonly used methods of welding, including fusion and resistance methods.

The development of a flux coated electrode for metallic arc welding has contributed to the ease with which the metal can be welded. The action of this flux was described briefly in a paper presented before the AMERICAN WELDING SOCIETY at their annual meeting in Buffalo, October 1932, entitled "The Welding of High Nickel Alloys." Since that time improvements have been made in the working characteristics, as well as in the manufacture of the rod.

The relatively thick coating employed permits maintenance of a uniformly short arc—reversed polarity being used. Since the molten metal is extremely fluid, good penetration is practical. This point is of particular interest in the welding of sheets less than 3/16 in. thick, where, in the case of butt joints, sufficient penetration must be obtained to permit grinding and polishing of the penetrated weld on the under side, while enough reinforcement must remain on the top side of the weld to provide strength and adequate stiffness. An example of the uniform and excellent penetration of Inconel welds is seen in Figs. 3 and 5*a*.

Gas welding affords another method of conveniently joining Inconel. As little difficulty is encountered in the gas or electric welding of pure nickel, no trouble was anticipated with this new metal, which has the characteristics of pure nickel only modified by the chromium addition. While no flux is ordinarily used in gas welding pure nickel, it was found that unless considerable care was exercised in gas welding Inconel, the chromium constituent would oxidize very readily when flux was omitted. For fool-proof welding a flux marketed by a prominent manufacturer of welding apparatus and accessory material and generally recommended for the gas welding of chromium bearing alloys, was found to be a convenient means of keeping the oxidation under control. This flux in the form of a thin paste, painted on the welding rod as well as on both sides of the sheets being welded and used in conjunction with a very slightly reducing flame, together make for sound, ductile welds of good strength.

Automatic gas welding is the method employed in the manufacture of small diameter tubing used for domestic electric ranges and in the dairy industry. Here, with temperature and atmosphere under accurate control, no flux is found necessary. A completely formed gas-welded Inconel heating unit shown in Fig. 7 is an example of quality welding.

2. Strength

In the case of an engineering material such as Inconel, a considerable interest usually centers about the tensile strengths of both the sheet and weld metals. Knowledge that the strength of the welded joint is sufficient is of particular importance so that butt joints can be used in design without hesitation and without fear of failure.

The physical properties of Inconel sheet in the annealed state are listed in Table 1 along with pure nickel, monel metal and mild steel for making a quick comparison.

Table 1—Physical Properties of Sheet Metal

	Ultimate Breaking Strength	Ductility		Modulus of Elasticity
		% Elong.	% R. A.	
Inconel	80–95,000	45–55	65–75	31,000,000
Nickel	60–75,000	43–53	65–75	30,000,000
Monel metal	65–80,000	35–50	65–75	26,000,000
Mild steel	50–55,000	25–30	60–70	30,000,000

NOTE: These properties are all of sheet metal in the annealed state.

Fig. 4—X-Ray of Weld Shown in Fig. 3. St. John X-Ray Service Corp. There is a complete absence of porosity, cracking or lack of fusion.

Table 2—Physical Properties of Welded Joints
(Composite Table of Both 1/16-In. and 1/8-In. Thick Sheets)

	No. of Tests	Breaking Strength, Lb./Sq. In.	% Elong.	Remarks
Unwelded plate	4	93,010	50.0	
Metallic arc welds (As welded, raw)	6	93,540	35.0	Broke in plate
Metallic arc welds (Dressed)	12	92,750	36.9	9 Fractures in plate, 3 fractures partly or wholly in weld

A series of tensile tests on butt-welded joints of both 1/16-in. and 1/8-in. thick sheet gages, which are fairly representative and tabulated in Table 2, showed that electric arc welds were developing strengths over 90,000 lb. per sq. in. and at the same time were 100% efficient. These welded joints were not subjected to any heat treatment subsequent to the welding operation. Heat treatment and corrosion resistance are covered later, but it might be noted here that heat treatment has not been found necessary either to restore adequate corrosion resistance in and near the weld or to improve strength and ductility.

3. Ductility

The ductility of sheet metal and weld metal is important to the fabricator, as the metal must withstand all normal forming operations. The elongation of sheet given in Table 1 and in curves (Fig. 2) is approximately 55% at room temperature while that of a welded joint is about 35% in 2 in. Elongation as determined on welded joints, while informative in connection with the complete joint, is questionable if applied independently to either weld or sheet. Their interpretation depends on the position of the fracture.

More convincing evidence of ductility so far as the fabricator is concerned is the ability to deform a weld, as for example, to turn a flange on a welded cylinder without any sign of failure. Deformed gas-welded tubing, showing no failure in either weld or tube after expansion of over 32% is illustrated in Fig. 1. A usual quick test of ductility is the bending of a weld, either parallel or transverse to the direction of welding. Inconel welds withstand this drastic elongation without any visible signs of failure, even when the welded plates are hammered back to back over their entire length.

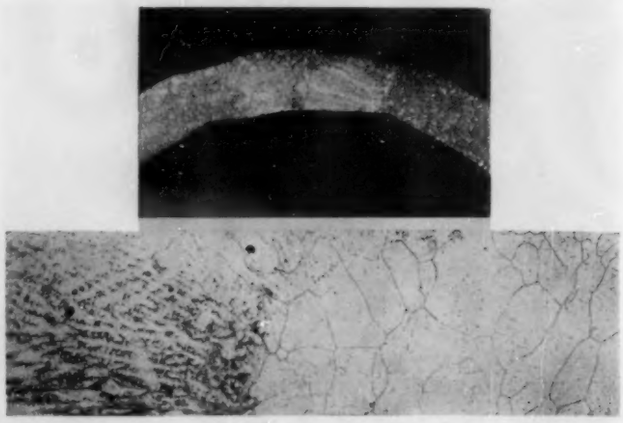
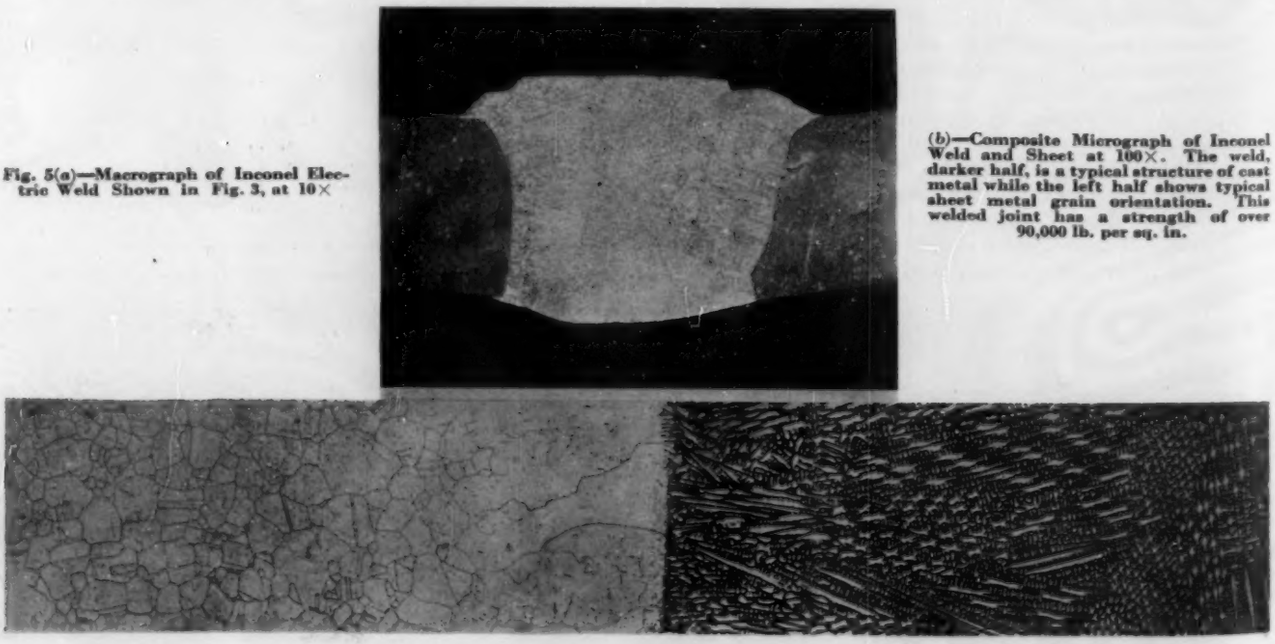


Fig. 6(*a*)—Photomacrograph of Inconel Oxyacetylene Weld at 14×. (*b*)—Photomicrograph of Weld in 6(*a*) at 100×

The small diameter Inconel gas-welded tubing, Figs. 1 and 7, is a good example of the inherent ductility of the metal. Strip in coil is formed into straight lengths of tube, then gas welded and swaged to size, annealed and finally coiled to make the flat heating unit of certain domestic electric ranges.

Reference to the curves in Fig. 2 for elongation and reduction in area at elevated temperatures will disclose that these are uniform from room temperature to about 700° F., then a gradual decrease in these values till at 1400° F. the ductility is quite low. This lowering of ductility is more or less characteristic of certain alloys and is referred to as the hot-short range. The practical significance of these two curves is that metal should not be worked or deformed around the 1400° F. temperature and that care must be taken to avoid setting up any stresses in the weld during cooling through this range if

Fig. 5(*a*)—Macrograph of Inconel Electric Weld Shown in Fig. 3, at 10×



(*b*)—Composite Micrograph of Inconel Weld and Sheet at 100×. The weld, darker half, is a typical structure of cast metal while the left half shows typical sheet metal grain orientation. This welded joint has a strength of over 90,000 lb. per sq. in.

Fig. 5(*a*) and 5(*b*)

cracking is to be avoided. Where normal care is exercised in fitting up a job so that butt seams are uniformly spaced and that lap joints are laid up tight before beginning to weld, little trouble is encountered. This point may become an issue if attempts are made to fill up unusually large holes resulting from improper setting up or burning through when welding, and where a large mass or quantity of weld metal must cool down together. However, even conditions such as these are easily met by following the proper technique.

4. Soundness

In dairy, as well as food handling equipment, interior surfaces coming in contact with milk products or food must be absolutely smooth and sanitary, with no sharp corners or depressions in the surface where bacteria may lodge and multiply. Sheet is seldom an offender in this respect, but welds have often in the past been a source of trouble from the standpoint of pits and porosity. Soundness of a weld is, therefore, all important and its lack becomes particularly evident if the weld is to be ground flush with the surface of the sheet and polished.

Further laboratory examinations of Inconel welds, other than the usual tensile tests, were believed useful to completely determine their soundness and with this thought in mind the following means were applied: (*a*)

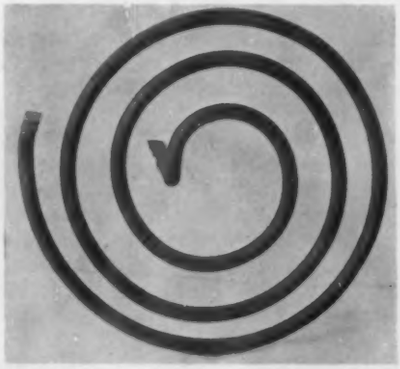


Fig. 7—A Calrod Heating Unit for Domestic Electric Ranges. Gas-welded Inconel tubing is required to withstand swaging and coiling operations in fabrication of this unit.

X-ray examination, (*b*) a type of nick-break test, (*c*) macro and microscopic examination of typical Inconel welds.

The exograph of the Inconel weld pictured in Fig. 3 (front and back views) is shown in Fig. 4. Examination will disclose a sound weld free of porosity, cracking, inclusions or lack of fusion. Incidentally monel metal electric welds, X-rayed at the same time, were seen to be equally sound.

Specimens for the type of nick-break test applied were prepared by sawing in a power saw through a portion of the depth of a 6-in. long weld made in $^1/_8$-in. thick sheet. The fractures of these breaks showed a fine uniform grain with no porosity.

So as to show up any possible imperfections immediately below the surface, as well as any through the center of the weld in both the X-ray and nick-break tests, these butt welds made with the metallic arc on $^1/_8$-in. thick Inconel sheet were left "as welded."

Both the macrograph at 10 magnifications and the micrograph at 100 magnifications in Fig. 5 are from a section of the electric weld shown in Fig. 3 and are evidence of the soundness of the joint and the weld. So that a thorough comparison might be made between the weld metal and the sheet, the single photomicrograph was

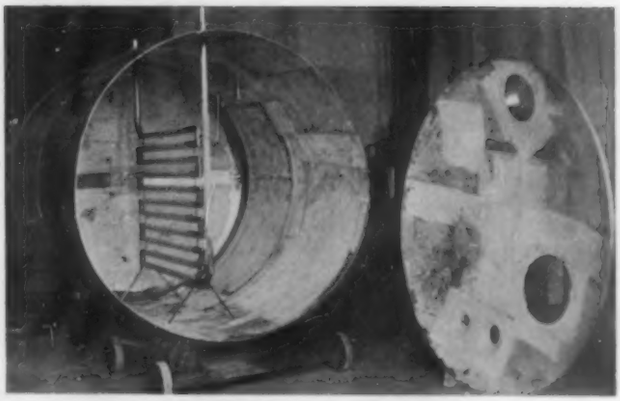


Fig. 8—2000-Gallon Inconel Ice Cream Aging Tank of $^1/_{32}$-In. Body Sheets and $^5/_{16}$-In. Heads. All are welded. Note welded coil. A protective paper covering is used to prevent scratching of polished sheet surfaces during fabrication.

prepared showing both these portions. The weld metal is the darker zone, which is characterized by the dendritic structure of solidified molten metal. This zone is really divided into two sub-zones; one at the extreme right being the general weld structure, while at the left half of the darker portion is the zone in which solidification took place more rapidly. There is an enlargement of the grain between the sheet and weld, really a zone of recrystallization. This zone is one which might be produced by heating a sheet to 2200–2300° F. and then quenching, a condition paralleling those met in electric welding.

For purposes of comparison a photomacrograph and photomicrograph of an Inconel oxyacetylene weld have been prepared and are shown in Fig. 6.

5. Weldable Thickness Range

The upper limit of plate and other sections met with in ordinary Inconel welding practice is not high because the high cost of the alloy always encourages the designer to use as light sections as possible. The sections used are usually inside the range of easy welding practice and problems of weldable thickness need only be considered in connection with light sections.

Under ordinary conditions it has been found that 18 gage (0.050 in.) is about the lower limit which can be conveniently welded with the metallic arc without undue buckling of the sheet. Gages lighter than 18 gage are usually used as covers over insulation and must have one side polished. Where it is considered worth while to exercise greater care in clamping of the sheets, lighter gages may be metallic arc welded, but not without some

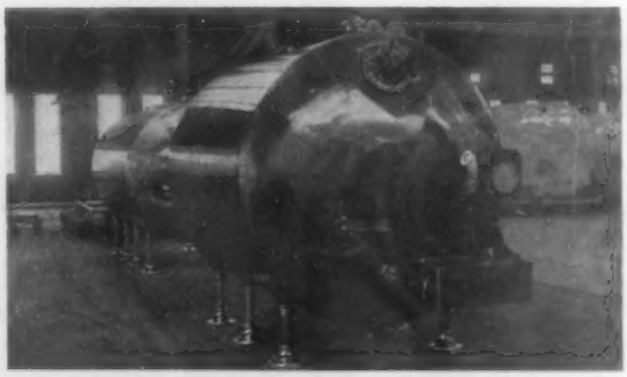


Fig. 9—Two Completed 2000-Gal. Inconel Aging Tanks. The high finish to which Inconel can be brought can be seen on the sheathing.

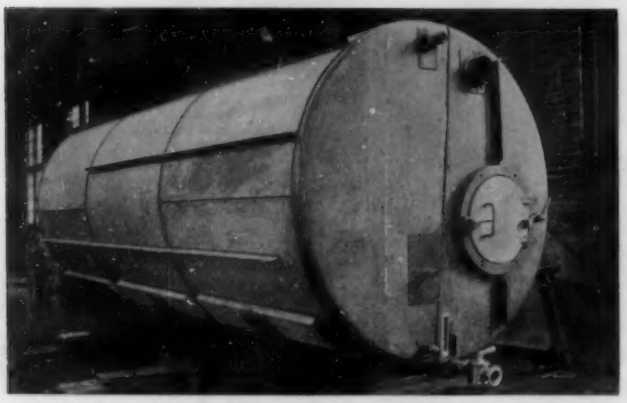


Fig. 10—Inner Shell of Inconel 3000-Gal. Milk Storage Tank. Insulation and outer sheathing have not yet been put on. The Inconel is 16 gage all are welded.

practice. No lower limit need be set for acetylene welding, as this is dependent on the ability of the welder.

If an attempt is made to arc weld too light a gage, some difficulty will be encountered in buckling of the sheet. To avoid this to some extent, a jig or clamp is found advantageous in keeping the sheets in line. This procedure is recommended as highly desirable in many cases, not only with light gage but up to $^{5}/_{32}$ in. as well. In our experience in welding service a short time spent in proper clamping would often save hours of effort.

6. Finishing Welds

Practically all the surfaces of food and dairy equipment, not only the side contacting the food but the exterior surface as well, are polished to a satin finish. Of course, welds made in the fabrication of these units must be readily grindable and easily polished to the high finish required. Inconel welds are rough ground with coarse rubber bound high-speed grinding wheels, the finish then gradually brought up by using finer grits of emery glued to sewn cloth wheels. These processes are accomplished with reasonable ease.

The interior of an Inconel ice cream aging tank is shown in Fig. 8. The welds are ground and partly finished during course of fabrication, and as work nears completion the protective covering over the sheet surface is removed and the interior resurfaced and brought up to the high finish required. That an excellent finish is obtainable can be seen in Fig. 9 which pictures two aging tanks each of 2000-gal. capacity.

7. Ease of Repair

Frequently, despite the general excellence of welds and good welding characteristics of any metal, it is necessary to reweld an occasional imperfection. In the case of Inconel such imperfections often take the form of a slight, incomplete penetration, which in grinding down leaves a low spot or crevice that is objectionable from the standpoint of sanitation. This is quite easily "picked up" or "spotted." The usual care in removal of the flux from the previously laid weld and, in the case of a single small pit, using a circular movement of the electrode with a final breaking of the arc by a quenching of the arc and quick withdrawal of the electrode, produce a sound spot. A few minutes experience in the "spotting" of these small defects will be sufficient to develop the technique required.

8. Corrosion Resistance of Welds

Inconel having complete corrosion resistance under a great many conditions, some thought was necessary to select a solution in which to compare the corrosion resistance of various types of weld with that of the parent metal. If a solution were used to which the metal is completely resistant, it might well happen that the weld metal while inferior to the parent metal would still be unattacked. It was, therefore, thought best to select a solution which Inconel could withstand in practical use, but which would produce a visible or measurable attack. This solution was found in an acid refrigerating brine. Refrigerating brine often becomes acid in use and then will attack most metals destructively. While its effects can be measured on Inconel, the metal is not destroyed.

In a long series of laboratory tests it was found that any weld which would pass ordinary inspection for soundness would resist corrosion at least as well as Inconel sheet. Welds which have been in service for long periods in these brines and under other corrosive conditions have been inspected and found to be free from corrosion.

Strain and recrystallization in the neighborhood of welds may affect the corrosion resistance. Analysis of the test results mentioned above shows Inconel to be relatively little subject to such effects.

Recent experience with stainless steels leads naturally to the question, particularly on a chromium nickel alloy, as to whether there may be precipitation of carbides during welding and resulting deterioration known as weld decay. It is now well known that these effects in the nickel bearing stainless alloys can be successfully counteracted by (*a*) heat treatment after welding, (*b*) use of low-carbon metal, (*c*) special addition agents, (*d*) low-iron content.

Fortunately the alloy Inconel is not at all subject to the deleterious effects of carbide precipitation and precautions to prevent weld decay are unnecessary. Laboratory studies were made subjecting welded specimens to a solution of copper sulphate and sulphuric acid, a method used extensively for testing the embrittlement susceptibility of metals. After 100 hours the Inconel specimen had lost none of its ductility, while metal susceptible to embrittlement, exposed for the same length of time, had suffered serious intercrystalline attack. This is due to the low-iron content of Inconel, the embrittling effect of carbide precipitation not being of importance except where the iron is very much higher than is the case in this alloy.

In conclusion it can be said that the welding of Inconel has been highly developed through extended laboratory tests in conjunction with wide field experience. Tensile and bend tests have shown Inconel welds to be strong and ductile, while X-ray and microscopic examination have shown them to be sound. As a method of joining, welding is recommended on the basis of knowledge of what has been and can be accomplished.

Shop Set-Up for Fabrication of Welded Machinery

By R. R. KONDAL

†Paper to be presented at Fall Meeting, American Welding Society, Detroit, Oct. 2nd to 6th, by R. R. Kondal of The Wickes Boiler Company.

IT IS the intent of this paper to bring forth the information and requirements which we, through our experience, have found necessary in the prefabrication of large welded machines and other articles. By the statement large articles it is meant to exclude only the small pieces which would come under the head of Purely Production Work. There are very few shops that could afford the set-up given herein; however, certain types of work do not require the complete shop set-up. To be able to take care of all work in this line it is necessary that the following set-up be available.

I. Research

Before a job is accepted a complete test should be carried out to definitely determine what could be expected in the completed job. This requires a Chemistry and Metallurgical Laboratory containing all necessary equipment to carry tests and analyses on any type of metal. It should be equipped with a Universal Testing Machine to carry physical tests on the different types of metals. These should include tensile strength, ductility, hardness and fatigue tests. We will assume that we have a job containing parts of stainless steel welded together. The laboratory should be equipped to find the strength and corrosion properties of the weld that we have already found through research. Another example would be a steel article subjected to high temperatures after welding. High temperatures produce a galvanic action between the weld and the parent metal and unless our laboratory is equipped to carry tests of this nature under heat conditions it is possible that the galvanic action would be so great as to corrode the weld entirely away or speed the corrosion of the parent metal itself. In other words, we must be equipped to know how closely the weld resembles the parent metal.

Recently we completed a large flywheel about 6 ft. in diameter and weighing around 2000 lb. This flywheel was to be operated at a speed of over 600 revolutions per minute; the rim of a necessity was quite thick and large and welded together at two locations. If this weld had been porous it would materially affect the balance of the flywheel. The laboratory should be equipped to check up the porosity of the weld.

In the case of a broken steam hammer head that is welded together we must know before the job is started whether a weld could be deposited on this hammer which would have the same hardness as the hammer itself; the reasons for this are plainly apparent. Research equipment enables us to know our product and avoids a great deal of trouble due to a job not standing up after it has been in operation—this failure due to lack of knowledge before the product is completed. The drafting room should have available all research information and should strictly adhere to such information in the design of the structure.

II. Design

A complete designing or drafting room should be available that would be able to design the product in a preliminary way before the job is accepted, and to make the detail drawings before the job is sent to the shop. These detail drawings should contain all information including the types of steel, the type of weld, the type of welding rod and any other information that the shop might desire. The drafting room should understand to a fair extent the shop procedure in building the product. The checker of the drawings should be thoroughly versed in every operation that the product takes through the shop because it is primarily the design and secondly the cost of fabricating that will obtain or lose a job. The checker should then take the prints to the Schedule or Production Engineer and go over the drawings completely with him, telling him just what operations must be performed so that this Production Engineer can provide room in the shop and set the delivery date. The drawings then go to the layout man in the shop.

III. Stock

The layout man must have stock to work with. It is his duty to keep a record of this stock for reorder when it becomes close to being used up, and it is also important that he use the steel most economically to prevent excessive waste. It is a good idea to have each layout man's waste stacked up in one pile; this tends to form a little competition among the layout men to see who can keep the smallest waste pile.

We have found that the most suitable steel to carry in stock consists of the following characteristics and analysis:

Tensile strength—55,000–65,000 lb. per sq. in.
Yield point—50% of the tensile strength
Elongation in 8 in. found by dividing 1,500,000 by the tensile strength with a minimum of 20%
Carbon content—0.30%
Manganese—0.30 to 0.60%
Phosphorus—Not over 0.04%
Sulphur—Not over 0.05%

The most suitable thicknesses of plate found were as follows: $\frac{1}{4}$ in., $\frac{1}{2}$ in., $\frac{3}{4}$ in., 1 in., $1\frac{1}{4}$ in., $1\frac{1}{2}$ in., $1\frac{3}{4}$ in., 2 in., $2\frac{1}{4}$ in., $2\frac{1}{2}$ in., $2\frac{3}{4}$ in., 3 in., $3\frac{1}{2}$ in., 4 in., $4\frac{1}{2}$ in., 5 in., $5\frac{1}{2}$ in., 6 in., $6\frac{1}{2}$ in. and $8\frac{1}{2}$ in.

We also found that it is quite necessary to carry the following sizes of round bars: $\frac{1}{2}$ in. dia., $\frac{3}{4}$ in., 1 in., $1\frac{1}{4}$ in., $1\frac{1}{2}$ in., $1\frac{3}{4}$ in., 2 in., $2\frac{1}{2}$ in., 3 in., $3\frac{1}{2}$ in., 4 in, 6 in., 9 in., 12 in., 14 in. and 16 in.

The stock must also include standard size channels, I-beams and angles, and acetylene and oxygen for cutting and the necessary stock of different size welding rods.

IV. Layout

The layout man must have the necessary tools for doing layout work on steel or other metals, must be thoroughly familiar with reading blue-prints and the way in which the job is built. A layout man in very many cases can see something on the drawing that should be changed to reduce the cost of construction and still keep the job as strong as it should be. He should have the information on the drawings as to

what the machine is to be used for so he may get an idea as to whether the job is primarily intended for strength or beauty. For instance, we will suppose a job is to be used as a machine base with most of the base buried in concrete or down in a well; if the layout man did not know that this job was to be used for strength, he is very likely to grind the rough corners off to make it beautiful. All tolerances must be given, if only enough to inform the layout man whether the job is to check within 1 in. of the blue-print dimensions or within a few thousandths. He must be familiar with the machine shop practice so that he will know how much to allow in different locations for cleaning up or machining.

V. Fabrication

From the layout man the job goes to the cutters. The shop must be equipped with either gas, acetylene or other types of high B. t. u. gas cutting apparatus. This should include several hand torches, a machine operated straight line burning torch and a machine operated template torch for cutting small pieces automatically, such pieces to be used for bosses, door hinges, etc., where a number of them the same size and shape are usually required. The straight line machine burning torch should be equipped so that it can be tilted to burn a bevel edge; in some cases this bevel edge is necessary for welding. A tilted torch can cut the plate and bevel the edge in one operation. A manifold to enable several oxygen and gas tanks to be connected together is necessary for burning the exceptionally heavy material, where the volume of gas and oxygen is too great to be supplied from one tank without reducing the pressure at too great a speed. For plate thicknesses under $^5/_8$ in., power shears should be used to cut the plates and, like a straight line torch, should be capable of beveling a plate. The shop should be equipped with both a table planer, a plate planer and a boring mill, the table planer for planing the edges of the smaller parts where a machine fit is required before welding or to plane the bevel on to these parts for welding where this bevel cannot be put on with the torches or shears. The plate planer should preferably be about 20 ft. long to take care of pieces used for ways in machine beds.

The shop should be equipped with rolls capable of rolling up plate of about 1-in. thickness by an 8-ft. width, hydraulic presses to take care of heavier plate which the rolls cannot form. These presses should be equipped with dies of several types that would cover the usual radii called for and should be capable of bending a sheet of 5-in. thickness cold. Above this thickness it is necessary that furnaces or open fires be available for heating the thicker plate before pressing. For former corners on plate up to $^3/_8$ in. thick a break of about 8-ft. width must be available. In several cases angles are used for flanges or stiffness and angle bending rolls are very desirable rather than bending such angles by hand. We have had jobs come up where the last piece welded on to the work had to be welded by the use of plug holes drilled through the plate, therefore drill presses of about $1^1/_4$-in. diameter capacity must be used in certain instances. Hand grinders and air chipping hammers are very handy in fitting the job together. The fitting or tacking up of the work should be carried out on a large, heavy level table with plenty of clamps and jacks available to hold the parts in place for tack welding. On an exceptionally large job where the level table would not handle the massive structure and great weight it is sometimes possible to jack the base plate up level directly on the floor of the shop and use this for locating and leveling up the rest of the parts. It is recommended that one large overhead crane be available of about thirty tons' capacity with several small gib cranes or hoists, preferably operated by hand.

The layout man must be in complete charge of the job from beginning to end and made responsible for the completed article. After it is tacked together it is ready for the actual welding.

VI. Welding

It is not the purpose of this paper to deal with the subject of welding so we will pass on to the next and last requirement for a complete job.

VII. Finishing Requirements

After the job is completely welded it is ready for the annealing furnace and we believe the annealing of any welded job is absolutely necessary to obtain a perfect product.

Any type of welding sets up strains directly in the weld and in the parent metal; the strains cause the steel to be of a different type in different parts of the article. In some cases the steel is stressed beyond the yield point, which gives us a dead or inelastic product. Unless the product is annealed or stress-relieved it will have different strengths, hard spots and will most certainly warp to some extent after it is machined. If it is to be used in a place where the corrosion is fast we find that a strained structure corrodes very much faster than one whose stresses have been taken out by heating. The annealing furnace should be capable of heating the object to at least 1200° slowly and uniformly and closed to cool slowly and uniformly. It should be large enough to take care of the greatest size job that would in all probability ever be made in the shop or shipped on a standard flat car. Several jobs are designed in such a manner that warpage takes place to quite an extent while welding and the annealing furnace can be used not only to take the strains out but by leveling the job up and weighting down it can be used as a straightener and still leave no stresses in the finished product.

We have found the X-ray a very valuable adjunct in checking up the steel and the welds for cracks or defects during fabrication. To properly finish the article prior to machining the steel should be sand-blasted and the paint or metal coat applied at this point, the product is then ready to send over to the machine shop for final machine work.

Internal Stresses in Welds

By C. T. SCHWARZE

✦Paper presented at the Thirteenth Fall Meeting American Welding Society, Detroit, Oct. 3, 1933. C. T. Schwarze is Professor of Civil Engineering, New York University. Report presented to Fundamental Research Committee.

RESEARCH into mechanical problems results from a very human impulse—curiosity. Curiosity may have killed the cat, but it is also responsible for our knowledge of the forces of nature and their effects. In general, there are two kinds of research. First, that of the manufacturer who detects flaws or shortcomings in his product and feels the need of improvement. He may be actuated by consideration of personal pride in workmanship, but is also keenly aware of competition from other manufacturers. The other kind of research is scholastic. It is more leisurely, is dissociated from any idea of monetary gain or loss and is actuated by a desire for hidden possibilities. It may be called the mechanics of "art for art's sake."

May it be said at the outset that the purpose of this short paper has a positive and a negative side. On the positive side it may be stated that while the amount of research is comparatively small and practically but a beginning that has promise, it has a definite purpose. The subject matter is here presented to stimulate discussion on both its possible usefulness and the direction that such research may take. We are open-minded and willing to undertake any fundamental research that our laboratory facilities and available time may permit. On the other hand, may it be said that the research herewith reported has no connection whatever with existing standards of testing welds. Most of the tests were made in bending, for example, but such tests were made solely for the purpose of conducting fundamental research in as pure a method of testing for behavior of welds under stress as could be devised. Our bending experiments have no bearing upon the so-called "free-bend" tests specified by the A. S. M. E. code, either as to the method of test or to the test itself. We are not seeking to revise that specification nor even to try to improve it. This also applies to any other specified test, proposed or now in use, for commercially determining the effectiveness of a weld. Our aim is simply to discover what goes on in a weld when that weld and its base metal are under stress.

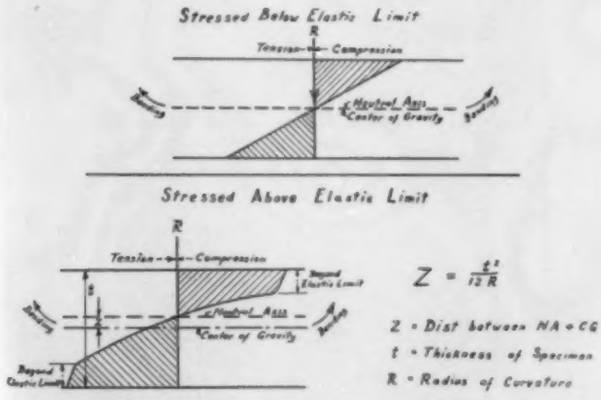


Fig. 1—Stress Distribution across a Bent Bar

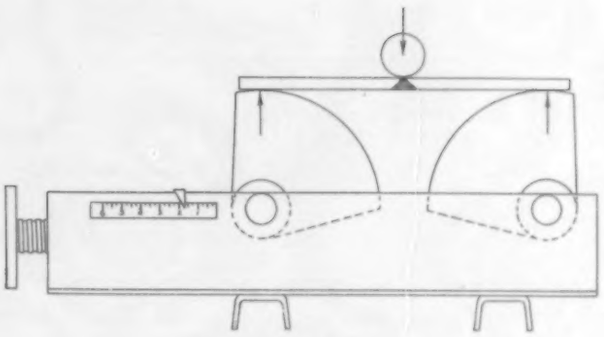
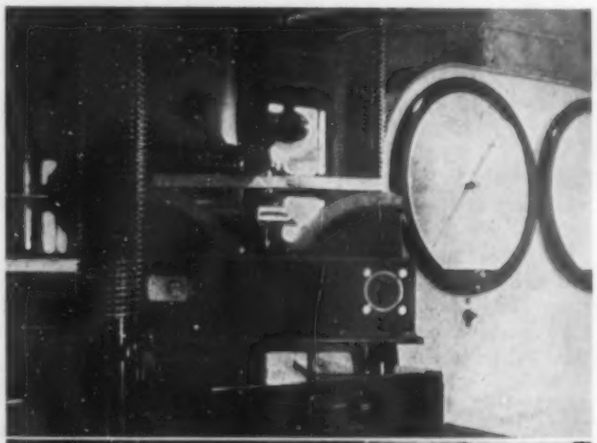


Fig. 2(a)—Cold Bender

Welding is no longer in the experimental stage when utility is considered. Civil Engineers are interested mainly in structural welding. That the profession has recognized the salient excellence of welding is evidenced by the welding codes that have been incorporated or are being incorporated in building codes of cities. Therefore, research conducted at the present should be fundamental and should concern itself with what goes on inside welded joints under stresses that may occur when used on construction. It is the object of this paper to briefly discuss such research into one kind of joint to get at fundamental behavior.

In the early days of the late World War it was discovered that ordinary tensile and compressive tests of munition materials were not conclusive when extraordi-

Fig. 2(b)



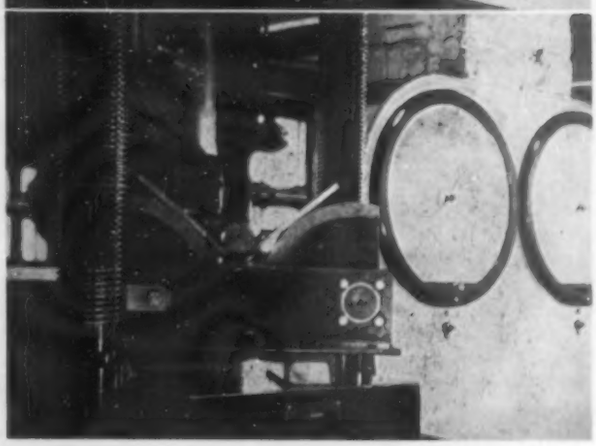


Fig. 2(c)

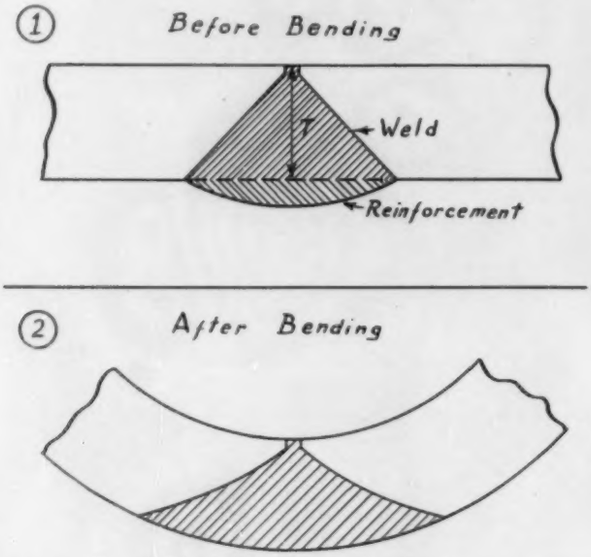


Fig. 3—Effect of Bending on Welds

nary usage became necessary. Various new methods of testing were introduced, some of which are still in use. Tests, which demonstrated weakness most readily, were made in some form of flexural stress. It was, therefore, expected that some form of bending in welded joints would prove most helpful in detecting dissimilarity in stresses between base metal and welding metal in a welded joint.

Stresses in bending may be accomplished by ordinary beam tests or by the cold bend. For the purpose of tests at New York University beam specimens were not feasible because of size. Cold bending of coupons gave better promise of quantitative as well as qualitative results. The older standard method of cold bending had to be ruled out for fundamental study because it did not permit the measurement of pure stress. Where a bar is clamped at one end and pushed around a pin, the material is crowded at the turning point without permitting natural expansion due to Poisson's law. Hence, there result abnormal compressions at the inner and abnormal tension at the outer side of the coupon at the turn, disturbing the neutral surface and giving only approximate indication of stress distribution as indicated in Fig. 1. Again, the older method of cold bending made the measurement of stresses highly difficult if not impossible.

Lately a cold-bending apparatus has been invented to be used with Southwark-Emery machines, which performs cold bending without apparently developing secondary stresses. It is composed of rocker bearings and a central plunger holding the pin to be used for bending. As seen in Fig. 2*a*, test coupons have point contact with the bearings at all times. The bending is accomplished in a more natural manner since the rockers move with the coupon. With such a combination most of the research was done. A few coupons, shaped for such tests, were tested in a universal machine for tension but the results were not so satisfactory. Figures 2*b* and 2*c* show coupons in the machine both before and after bending.

Single vee butt joint coupons were used with the throat of the weld in contact with the pin. While the ordinary butt weld has reinforcement, as shown in Fig. 3*a*, it was decided to dispense with this in order to secure better control of flexural stresses. Also, from Mr. Priest's excellent paper[1] before the New York Section, photoelastic studies by Professor Hollister seemed to indicate that reinforcement took little if any stress. For these reasons welds in our tests were ground flush with the base metal, as indicated in Fig. 3*b*. This also facilitated attachment of tensometers at a desired distance from the neutral surface.

Coupons for bending tests were of medium open-hearth structural steel, $^3/_4$ in. in thickness and were gas-welded with a No. 1 rod of the following approximate composition:

Carbon	0.18%
Manganese	1.00
Silicon	0.40
Sulphur	0.03
Phosphorus	0.02

This same rod was used in some of the tension coupons herein called "high-carbon welds." Tension coupons called "low-carbon welds" were gas-welded with a No. 7 rod of an approximate composition:

Carbon	0.06%
Manganese	0.20
Silicon	0.01
Sulphur	0.03
Phosphorus	0.02

Tensometers were placed as close to the outer fiber as possible and the distance to neutral surface carefully measured. An average curve for four of the coupons tested, which appeared to give best results, is shown in Fig. 4. The *E*-line of two of the coupons practically coincided with that of the base metal, the other two being somewhat at variance with the latter. To get this com-

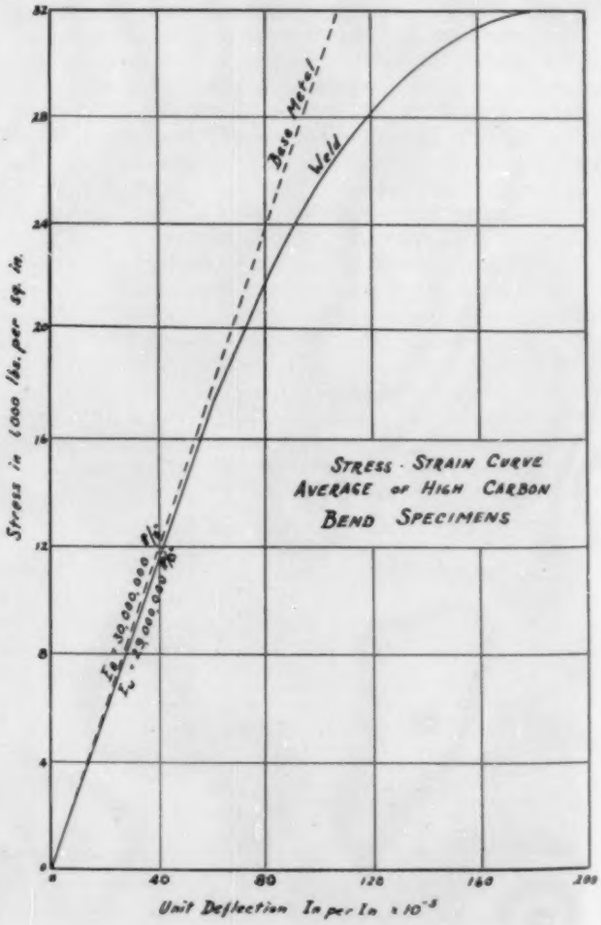


Fig. 4

[1] Journal American Welding Society, Vol. 12, August 1933, pp. 9 and 10.

parison two Huggenberger tensometers were employed, one on the base metal alone and one on the weld alone. Coupons were also gas-cut to a width of three times their thickness. As can be seen in the figure, readings could be taken well beyond the elastic limit of the weld material before tensometers reached their reading limit. Ultimate strengths varied from 92,500 to 104,000 lb./sq. in. Failure usually occurred by a separation of weld and base metal at one edge of the vee. This separation continued for a short distance and then the specimen broke through the base metal.

In the case of tension coupons some four results were taken as indicative of behavior under direct pull. The results of these tests are given in Fig. 5. It will be noted that the greatest variation in elasticity occurred in the "high-carbon weld." There were no bending tests of $^3/_4$-in. coupons made with a No. 7 welding rod so that no comparisons could be made there. While the *E*-line of low-carbon welds adhered more closely to that of the base metal, the ultimate tensile strength of high-carbon welds was higher than the others, approximating 55,000 lb./sq. in. for the high-carbon welds. Failure in each case was through the weld.

Conclusion

Because of limited time and the paucity of available test data it is manifestly unfair to draw definite conclusions. More research along this line has been planned, but some inferences of a tentative nature may be made.

First, while so-called pure tensile tests may show greater weakness in a weld it is not a fair usage test since welds in practice are not designed for pure tension and rarely, if ever, are subjected to that alone. Tension stresses, most likely, are small secondary stresses when they exist.

Second, a careful perusal of the excellent collection of data on welding for use in construction by Mr. Priest indicates that there are few, if any, welds which are not subjected in some form to bending.

Third, pure bending tests appear more readily to show up weakness in contact planes between base metal and weld. This is of importance in the making of welds since these tests show that inside safe limits weld and base metal appear to mutually function perfectly. Elastic limits in bend tests 18,000 to 20,000 lb./sq. in. are lower than those in tension and indicate a tendency of the weld to slip along the contact plane. Gas pockets along the fractured planes also show that there is such a tendency.

Finally, bending tests, as conducted, tend to eliminate secondary stresses and give greater assurance of true stress measurement. In older methods of testing definite size pins were specified for different thicknesses of metal. In the tests under consideration it was demonstrated that any size pin can be used without affecting the results.

Acknowledgment is hereby made for assistance in the conduct of this research to Mr. J. M. Keir of the Union Carbide and Carbon Research Laboratories for the fabrication of coupons and valued suggestions; also to Messrs. Henry A. Beekman, George W. Demeritt and Seymour Male, recent graduates in Civil Engineering at New York University, for work done in the testing and photo-elastic laboratories at the University.

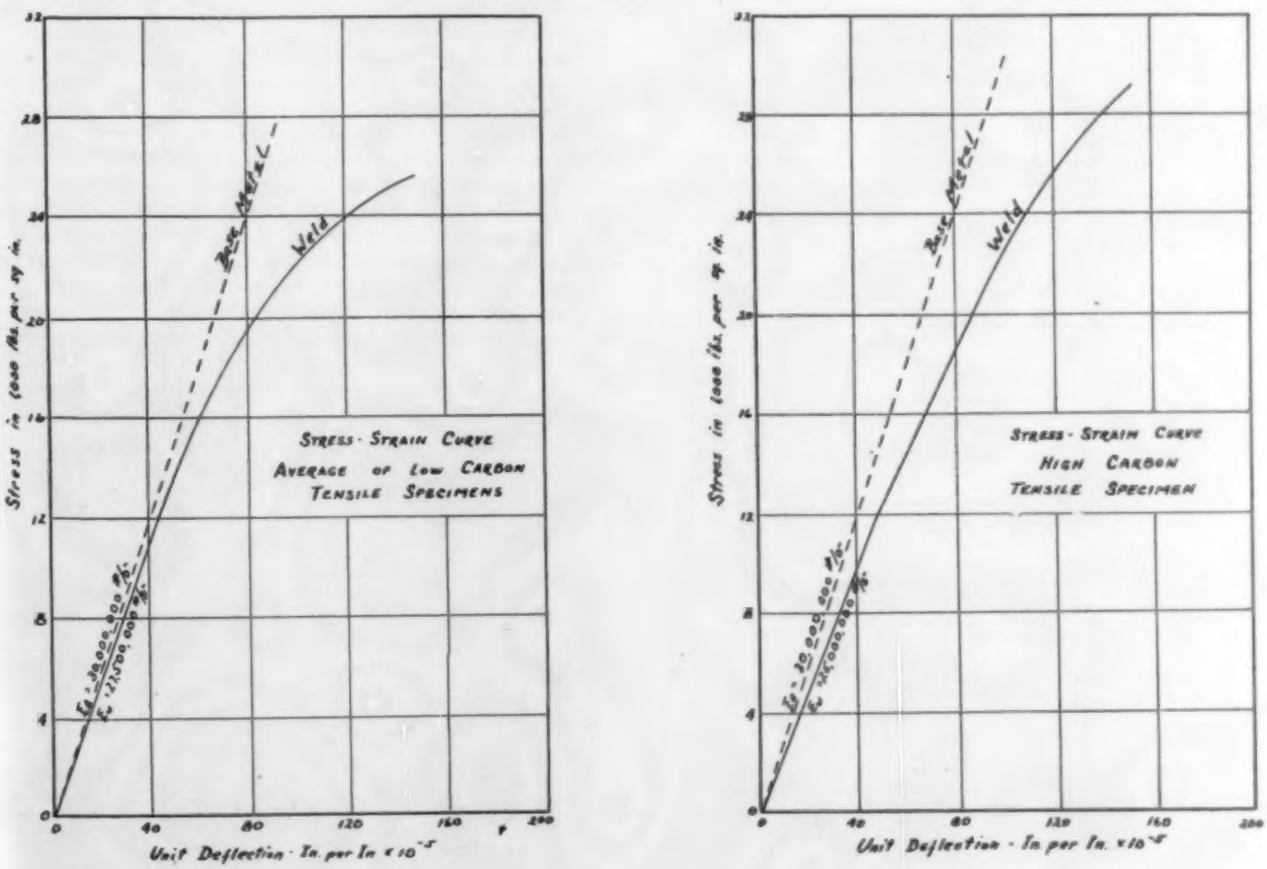


Fig. 5

Welding in a Large Shipyard

By G. H. MOORE, JR.

†Paper presented at Fall Meeting, A. W. S., Oct. 2nd to 6th, Detroit, by G. H. Moore, Jr., Welding Office, Prod. Dept., Newport News Shipbuilding and Dry Dock Company.

Introduction

ALTHOUGH shipyards exchange welding information, the problems peculiar to shipbuilding welding practice are little understood by those in other industries. Shipyard welding covers a wide range of processes and metals, and shipyard methods are undergoing changes in order that this comparatively new construction practice may be used to the best advantage. Adequate provision for further extension of welding is being made.

The purpose of this paper is to present outstanding features concerning the welding and gas-cutting processes used at the Newport News Shipbuilding and Dry Dock Company.

Due to fast moving developments and broad range of welding applications in this shipyard, only those items are presented which represent definite progress and which also indicate conservative but successful shipbuilding practice.

General Considerations

During the past fifteen years ship welding progress has been characterized by solutions of technical, management and production problems. Experienced ship owners and shipbuilders have required that each new welding detail be of high merit in order that nothing be done that might endanger sea safety. This has kept ship welding development on a conservative but sound basis. Sea performance is a very rigid examination of the shipbuilder's skill, but another test is that of economy, as satisfactory service performance combined with low building and operating costs are the critical factors to be considered both generally and from the welding view-point.

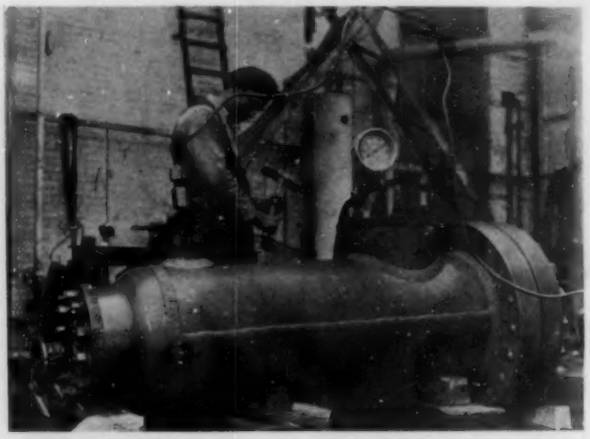


Fig. 2—Welded Oil Strainer—Tested to 2000 Lb. per Sq. In.

From a broad view-point the use of welding in shipyards was seen as a partial solution of those problems leading toward ships of improved quality. We have developed our welding with this idea in mind and have established many satisfactory precedents.

Classification societies, such as the American Bureau of Shipping, have actively assisted through their helpful interest. The Navy Department has greatly increased the extent and range of welding application on their ships in order to save weight and increase structural efficiency. Both of these organizations and the shipyards have cooperated in a manner beneficial to each organization. This shipyard has initiated and given considerable assistance toward use of welding for shipbuilding purposes.

Confidence in welded joints was acquired through careful application and observation of service performance; also use of welding required solution of organization, design, practice and classification problems. Each division in a shipyard has its proper duties to perform toward welding, in order that extensive and important use of welding may be acceptable. Progress along this line places welding in the every-day routine of shipbuilding.

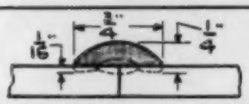
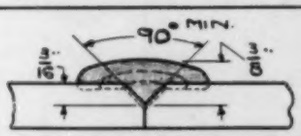
PIPE WALL THICKNESS (MAXIMUM)	DIAGRAM OF WELDED JOINT	WELD SIZE (MINIMUM)
1/8"		1/8" × 3/8"
3/16"		3/16" × 9/16"
1/4"		1/4" × 3/4"
5/16"		5/16" × 3/16"
3/8"		3/8" × 1 1/8"

Fig. 1—Pipe-Saddle Weld Butt Joints

1. Penetration or depth of vee, is included in the height of the weld for all wall thicknesses.
2. Use for working pressures up to 250 lb. per sq. in. and nominal diameters 12 in. and less.
3. Use next larger size weld for pipe wall thicknesses intermediate to those given. Example for 7/32-in. wall thickness, use weld size indicated for pipe having 1/4 in. wall thickness.

Development and Designs

During preliminary outlining of work on a contract welded designs are given consideration, and when the features desired by both the ship owner and the shipbuilder are obtainable by means of welding, the working drawings are developed with complete welding information. Drafting practice includes the use of AMERICAN WELDING SOCIETY welding symbols and nomenclature.

Designs for welding are grouped into the following classes: hull structural, machinery, tanks and piping and sheet metal.

During consideration of new welded designs it is often necessary to consult accumulated information and also

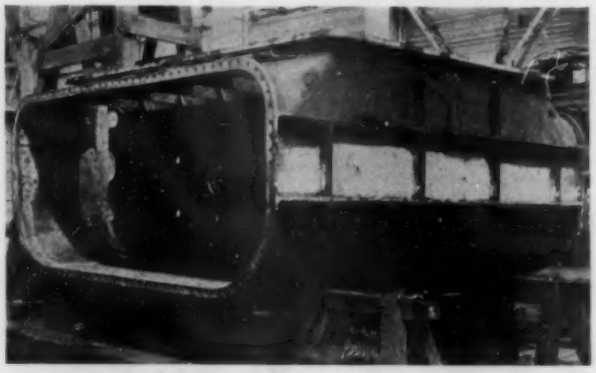


Fig. 3—Welded Underslung Steam Condenser Shell

determine the welding procedure and materials to be used in production. This is the critical stage of welding development, sometimes requiring experimental work before a decision is made.

Design practice has standardized many of the simpler and most used welded parts.

Well worked out ideas, clearly expressed, aid preparation of material, and the instructions on the drawing are followed during welding.

Because of the necessarily flexible nature of this complex and large organization, a central source of welding information and assistance is maintained.

Design strength values in general are based on 36,000 lb. per sq. in. ultimate tensile for mild steel. Other metals and special designs require particular attention. Many parts are designed because ductility and uniform strength make them possible.

Fillet welds are used more than butt welds but they are equally important. The location of these welds is such that the welding operator may readily make them of required size and shape.

Welding of longitudinal deck joints was preceded by study of available data and considerable experimental work. The filler metal in these joints is sufficiently ductile to ensure that all parts will work together.

Research for information usually anticipates actual needs, and welding tests are made to determine practicability of new ideas.

Extensive welding tests are conducted with many kinds of electrodes and base material because this is a very important welding design and production factor. Technique is also developed at the same time.

Electrode tests make possible the selection of one brand of electrode for each of the various base metals to be welded. The welding operator is taught the technique and procedure found by means of tests to be most suitable for the material and work to which he is assigned.

Warping problems are studied mainly during experimental work, but the application of correct procedure on practical work is much more difficult, since it usually involves flat and slightly curved large areas of plating. Shrinkage allowance is a part of the warping problem and residual stresses are kept to a minimum. The finished product must be pleasing in appearance, together with sufficient strength.

The designer and practical workman gain welding knowledge from carefully outlined full-size tests conducted on a practical basis, and complete data are prepared from each test in order that recommendations may be substantiated.

Experimental work is done so that costs may be decreased, which often assists easier production. Weld sizes are kept to a minimum.

Welding materials, equipment and practice are constantly gone over and improvements made wherever possible.

Processes and Practice

Oxyacetylene gas cutting has proved indispensable during preparation of parts for welding. Structural material is cut to size and shape, and production of irregular shapes is much simplified when gas cutting is used. Heavy parts, such as forgings, are readily assisted during their preparation as there is practically no limit to the thicknesses and shapes which may be gas cut to close dimensions.

Removal of rivets and damaged parts is an economical and important use of gas cutting and the time saved greatly assists speedy ship repairing.

Metal arc welding is extensively used, being the process by which 95% of ship welding is done. Covered electrodes are used to obtain weld metal more nearly equal in physical properties to ship steel, increase production, decrease cost and improve welding design and practice. The use of covered electrodes has advanced ship welding immeasurably and the intensive study which led us to extensive use of this ductile filler metal has proved worth while.

Welding current is obtained from multiple-operator

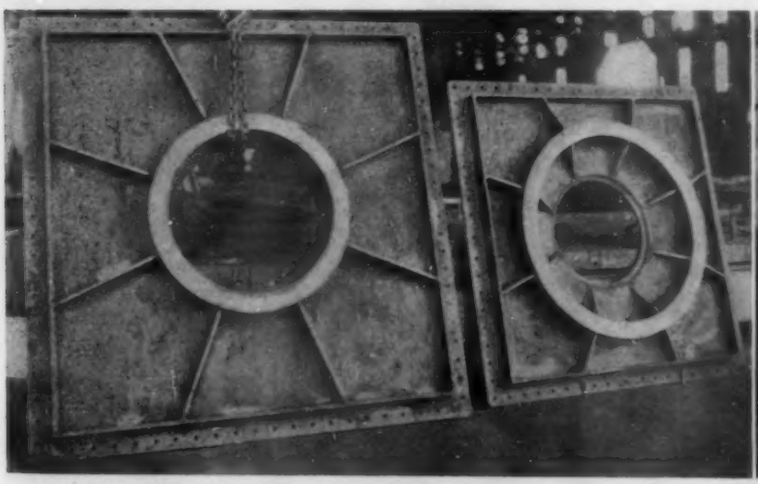


Fig. 5—Welded Test Foundations Used for Testing Hydraulic Turbines

Fig. 4—Welded Bow Chock

generators, and portable resistor units provide for individual current adjustment. Single operator units also fit into production in a number of places.

A wide range of metals and parts is welded by means of the metal arc process.

Gas welding is used principally for cast-iron repair, new non-ferrous production and on thin sheet metal as well as for building up worn surfaces.

Resistance welding has recently become of more importance when fabricating thin sheet metal bulkheads both in the shop and on the ship. Small miscellaneous parts of a wide variety of metals are often spot welded. Both stationary and portable equipment is used in order to meet working conditions. Portable equipment for attachment of small parts during outfitting has shown excellent possibilities.

Thermit welding is occasionally used to repair heavy parts, such as stern and rudder frames. Forged and gas-cut parts of new rudder frames have been joined together by thermit welds.

Heating prior to subsequent operations is often done by means of oxyacetylene gas, because it is speedy and economical.

Acetylene and oxygen gases are manufactured in our plants, being piped to stations located conveniently. Cylinders also convey these gases to other locations.

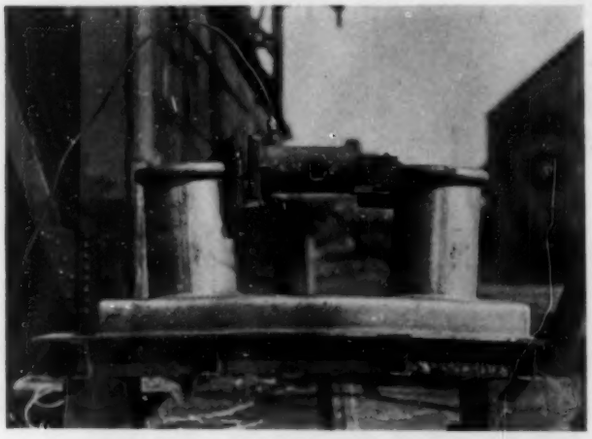


Fig. 6—Welded Mooring Bit

Practical considerations have divided production welding into four principal classes; namely, structural hull, machinery, piping and sheet metal. Ship repair welding may be classed separately as working difficulties are relatively greater. Paint, corrosion and explosive gases are usually encountered.

Each sub-assembly or finished item is prepared by experienced mechanics. Their practice is modified to suit production of welded parts, which includes use of gas cutting and heating equipment, adoption of simple means for holding parts together for welding and assembly tack welding done independently of regular final welding.

Other trades cooperate with welding methods in order that welding may be done in an economical manner. Cost accounting methods and proper use of budgets brought attention to more desirable distribution of welding labor charges, and a system is used which permits of each division doing that work which is properly its own. Responsibility is more clearly divided and personal incentive increased after this system was adopted.

Selection of men whose experience has been of a practical nature, and training them in our Welding School, is the best way to obtain reliable welding operators. Covered electrode technique is taught, particularly when used for vertical fillet welds. The regular welding training course includes all practical conditions, but pipe welding and other difficult jobs are given particular attention. The school record of a student welder is subject to approval by the Training Supervisor, after which fillet- and butt-weld qualification tests are given as a final examination.

Fig. 7—Welded Brackets of Fore Poppet Launching Saddle

Qualification physical results, when using covered electrodes to weld a butt joint, average better than 69,000 lb. per sq. in. ultimate tensile strength.

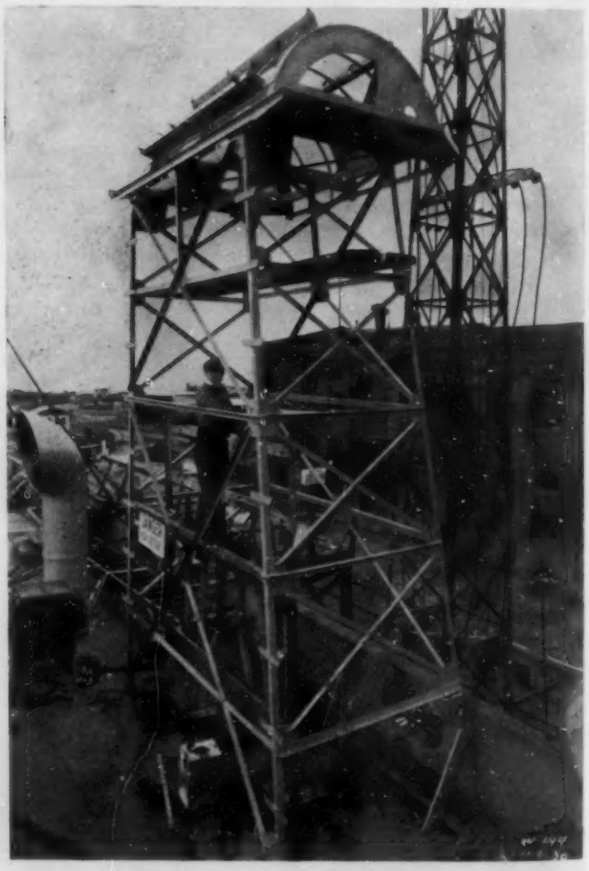


Fig. 8—Welded Transmission Tower for a Floating Power Plant

Nearly all experimental welding is done at the Welding School, and this permits those interested to become familiar with new ideas, being in the nature of a clearing house for practical welding information.

Considerable forge welding has been replaced by arc and gas welding at the forge and anglesmith's shops.

Stress-relief anneal, while not applicable to structural parts, is used to prevent warping of machined surfaces.

Piece-work and good preparation have increased the amount of weld metal deposited. More money is earned by the welding operator and his quality of welding improved at the same time.

Welding Production during 1932

An idea of the extent to which welding and gas cutting were used during the past calendar year, is indicated in part from the following data:

Acetylene gas was used to the extent of 1,800,000 cu. ft. and 7,500,000 cu. ft. of oxygen was used. Coal gas is used for preheating of large castings.

Approximately 335,000 lb. of electrodes of the heavy covered type were issued from stock for use on various contracts. Wastage allowance, when calculating the amount of deposited metal in the finished weight of a ship, is 30%. The electrodes used were principally of mild steel, but include stainless steel, monel and hard surfacing metals.

Gas-welding rods and metal spray wire used were 5000 lb., the most of which were of non-ferrous metal. A total of 340,000 lb. of filler metal was used during 1932.

Regular qualified metal arc-welding operators numbered 140, all of whom were trained and certified to do satisfactory welding in all welding positions. Specialty welding operators were kept to a minimum as they increase the complexity of labor distribution in the flexible system that is necessary in a shipyard doing repair, manufacturing and construction work. As only a few of these welding operators completed their training during 1932, most of them were well experienced.

Three regular gas-welding operators were employed, and a number of metal arc-welding operators also are capable of doing gas welding.

Men trained and assigned to do tack welding on subassembly work, and who have a regular trade, numbered 51. These mechanics were given a short intensive gas-cutting and arc-welding training course, planned to be most useful in their trade and at no expense to them except that their personal time was partially contributed.

A total of 302 men attended our Welding School for instruction in safety, gas cutting and heating, and metal arc welding practice.

Multiple operator, constant potential welding generators totaling 15,000 amperes and 10 single operator sets supplied current for welding.

During 1932 welding production on the aircraft carrier U. S. S. *Ranger* reached its peak.

Flat position deposition on favorable classes of parts ranged from 30 to 36 lb. of electrode per man each 8-hr. day. Welding production on other parts dropped considerably below this figure.

Including chippers and caulkers, maintenance and other workmen, a total of 275 were employed in the Welding Department.

Applications

Directly comparing the growth of our use of welding, our first applications were mainly for repair and on relatively unimportant items. Production welding is now given careful consideration because it is used on important parts.

All ships and machinery built during the past six years have used welding to some extent, the precedents established permitting a gradual increase on successive contracts, and the greatest welding progress has been on ships for the U. S. Navy.

Welding on Navy Department ships has an advantage over merchant ships. The latter requires owner's and operator's consent for welding, and approval of the classification society, the shipyard in this case often initiating welding applications and using its own welding methods.

The Navy Department specifies the extent, design and welding practice in a direct and orderly manner. Welding done on the 10,000-ton cruisers, including the U. S. S. *Houston* and U. S. S. *Augusta*, taught lessons that resulted in more complete specifications for subsequent ships, including the aircraft carrier U. S. S. *Ranger* now nearing completion. During early stages of preparation for building the U. S. S. *Ranger* every possible opportunity was developed in order to improve the desirable welding in her construction. Marked advancements in our practice resulted from this effort.

Merchant ships under construction during past years have used welding extensively on minor parts, principally where it was acceptable to other trades. After experience was gained more important parts were welded. Rudders, masts, auxiliary foundations, water-tight doors and hatches, all kinds of fittings, pillars, brackets, miscellaneous bulkheads, decks not principally for strength purposes, condensers, tanks, ventilation ducts and nearly all piping systems are now acceptable as standard welded parts.

Flanges are welded when pipes must be removed, but the saddle weld shown in Fig. 1 has been often applied during the past three years, being used because better pipe joints may be obtained. Experimental work was done to eliminate any possibility of globules forming inside the pipe. After a very satisfactory technique had been developed, a large number of specimens were tested hydrostatically, removing any doubt of practicability. The dimensions of the welds shown were those obtained when covered electrodes were used. The amount of weld metal was also reduced to a minimum consistent with all of the other factors involved.

Welded pipe is extensively used and piping systems operating pressures range up to 800 lb. per sq. in. Care is taken to maintain a constant weld throat dimension for branch pipes. Forged and cast fittings are used to simplify welded pipe design and to assist uniform smooth flow with least resistance.

The welded oil strainer body shown in Fig. 2 was tested to 2000 lb. per sq. in. It has a 1-in. thick shell, and the forged head on one end was more desirable than a dished head with welded boss to take studs. Condenser shells similar to those shown in Fig. 3 and large tanks are part of our standard regular practice. All individual tanks for use on ships are welded, except that rivets are used occasionally to avoid warping of large flat surfaces.

Forming of the plates for a bow chock, Fig. 4, formerly made of cast steel, was readily done at reasonable cost.

A large welded stem was also made of formed plates on which welding was done and varied in acuteness of angle from the formed plate welded forefoot, or bulbous bow, to the already described welded bow chock. This entire welded stem is a creditable job of plate forming for welding.

Model hydraulic turbines are tested in our hydraulic flume on the foundation bases shown in Fig. 5.

The safe working stresses produced in the welded bitt during test, Fig. 6, were sufficient to permit use of the

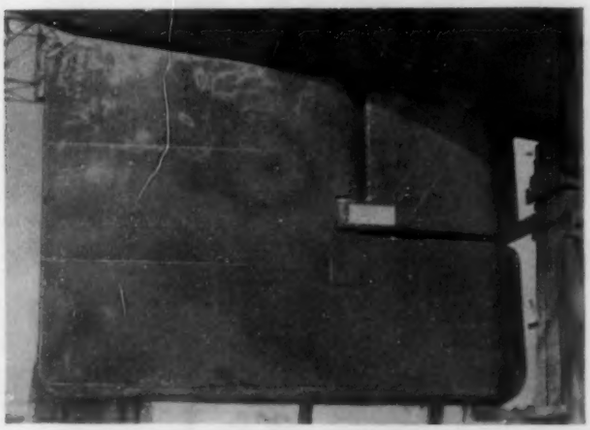


Fig. 9—Welded Balanced Type Rudder

largest hawser. The weakest point of this design was found in the base plate near one and between the barrels. Deck beams, plating and intercostal members were welded to the bit in order that ship conditions would be simulated.

The foregoing five illustrations represent parts formerly made of castings but which are now designed for welding.

Structural items usually welded are represented by the illustrations in the following figures. Photographs of large welded bulkheads and decks are difficult to obtain and, therefore, cannot be satisfactorily illustrated.

Simplified fore poppet saddles are possible when they are welded and in Fig. 7 are shown the brackets of some saddles used during launching of a large ship.

The Floating Power Plant "Jacona" generates electricity which is transmitted through cables attached to the tower shown in Fig. 8. Ship movement caused by tidal and wave action required a curved upper section.

Forged and cast parts are metal arc welded together to form small rudder frames suitable for tugs and to which side plates are welded.

The balanced type rudder shown in Fig. 9 weighs approximately 40 tons. The main portion of the frame is of cast steel but the arms and plates are of welded mild steel. Due to small cellular construction, access for welding was provided through welded manhole size plates. Watertightness and strength require that all rudders be of welded design.

Girders and trusses, one type of which is shown in Fig. 10, are designed for welding to obtain maximum strength with minimum weight. Riveted joints were used for erection purposes only.

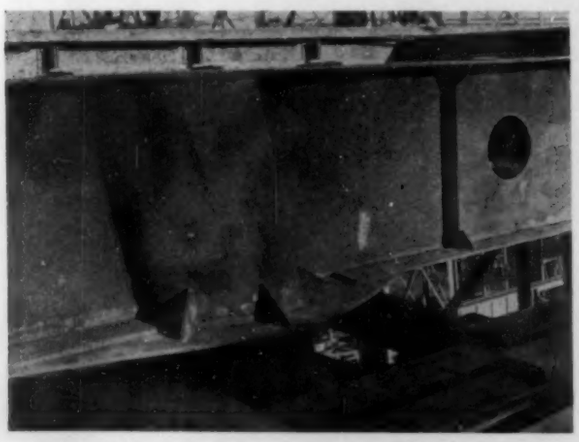


Fig. 10—Welded Plate Girder Supported on Cylindrical Columns

The type of welded stiffener shown in Fig. 11 is designed to save weight. The web, face plate and bracket are welded together in the shop and straightened before attachment to the welded bulkhead plating. Some bulkheads use riveted angles on one side for adjustment purposes during erection.

As contrasted to Fig. 11, the type of stiffener and bracket shown in Fig. 12 was developed to expedite erection and improve strength, but no effort was made to save weight. Puncturing of inner bottom and deck plating for rivets is avoided when welded brackets are used. This bracket is simple to fabricate. The plate bracket flange is turned toward the channel flange, and its both ends are welded all around. The bracket is lapped on the stiffener web, making erection a simple operation.

Fig. 11—Welded Stiffener and Bracket for Bulkheads

Fig. 12—Welded Type of Stiffener Bracket for Merchant Ships

Approximately 25 masts of large size have been entirely welded. Pipe sections of proper shape and diameter are made by welding semicircular plates. These sections are butted together and welded, care during every step being taken to avoid warping, which would spoil the appearance of the finished mast. Tables for cargo booms were often added to these masts. Fittings for attachment of topping lifts and stays are passed through gas-cut holes in both sides of the mast and welded in place.

Machines and buildings for plant purposes use a large amount of welding and all of the important plant pipe-lines are completely welded.

Machinery, boiler drums and other parts for use on ships, bought from manufacturing plants, are usually of welded construction.

Conclusions

Welding in shipbuilding has long since passed the experimental stage and is now looked upon as a part of every ship. The extent to which it is used depends

upon the knowledge of the designer, the confidence of the owners toward welding and the facilities of the shipyard for doing reliable and extensive welding.

The saving in weight due to welding is a point that no designer can afford to overlook. He also finds it possible to obtain greater joint efficiency and better tightness of structure.

Welding must pay its way, so that welding is rarely used unless there is some advantage in using it. These advantages in shipbuilding are many, among which may be mentioned: ensuring of water and oiltightness with least effort and cost, saving in weight, saving in forming of plates and shapes, greater flexibility for production of a large variety of parts, decreased handling of material, saving in space on the ship and simpler construction.

Classification society rules, AMERICAN WELDING SOCIETY welding codes and Navy Department specifications are aiding standardization of welding on a reliable basis, as their requirements are based on design and practical experience of past years.

A great many serviceable precedents are guiding favorable decisions toward continued use of welding on similar parts.

The use of ductile weld filler metal, obtainable from heavy coated electrodes, has gone a long way toward obtaining welded joints with physical properties equal to the metal joined.

Satisfactory welds are obtainable for the production of parts which include many kinds of metal, and new metals seem to require welding when their best use is desired.

Because of the importance now assigned to welding, organization and management problems have increased. These problems have been solved successfully and welding is now included as a necessary part of construction in a manner formerly thought impossible.

Welding and gas-cutting processes are an integral part of shipbuilding practice.

Acknowledgments

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